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OXYGEN AND THE NATURE OF ACIDS.

[These selections from Priestley's account of the discovery of oxygen and from Lavoisier's first formal presentations of his theory of acids are classical examples of scientific work which will always be worth reading. They have also the historical interest due to the fact that the discoveries they describe served as the turning-point of chemistry to the paths it has since followed. The dates of publication were respectively 1775, 1776 and 1777. We realize the progress of the century when we remember that these experiments are now among the first in an elementary course. These two papers are also representatives of two well-defined types of scientific advance; Priestley's discovery was one of the happy accidents that often reward the investigator, one of the cases where he reaps a hundred fold, while Lavoisier's work was the result of gifted insight and careful consideration of the entire range of phenomena concerned. Lavoisier had, as is shown in this paper, the faculty of giving the right meaning to the data acquired by others. The phlogiston theory is now so much a matter of antiquity that it seems proper to give the modern equivalents of some of Priestley's terms: Air is used by him in the modern sense of gas, dephlogisticated air=oxygen, inflammable air=hydrogen, phlogisticated air=nitrogen, marine acid air=hydrochloric acid gas, fixed air=carbon dioxid, nitrous air=nitric oxid (N O), dephlogisticated nitrous air=nitrous oxid (N_2O), vitriolic acid air=sulphur dioxid, mercurius calcinatus=red oxid of mercury.]

ON DEPHLOGISTICATED AIR.*

BY JOSEPH PRIESTLEY.

THERE are, I believe, very few maxims in philosophy that have laid firmer hold upon the mind than that air, meaning atmospherical air (free from various foreign matters, which were always supposed to be dissolved, and intermixed with it), is a *simple elementary substance*, indestructible and unalterable, at least as much so as water is supposed to be. In the course of my inquiries I was, however, soon satisfied that atmospherical air is not an unalterable thing; for that phlogiston with which it becomes loaded from bodies burning in it, and animals breathing it, and various other chemical processes, so far alters and depraves it, as to render it altogether unfit for inflammation, respiration and other purposes to which it is subservient; and I had discovered that agi-

* From 'Experiments and Observations on Different Kinds of Air.' London, 1775.

tation in water, the process of vegetation, and probably other natural processes, by taking out the superfluous phlogiston, restore it to its original purity. But I own I had no idea of the possibility of going any farther in this way, and thereby procuring air purer than the best common air. I might, indeed, have naturally imagined that such would be the air that should contain less phlogiston than the air of the atmosphere; but I had no idea that such a composition was possible.

It will be seen in my last publication that, from the experiments which I made on the marine acid air, I was led to conclude that common air consisted of some acid (and I naturally inclined to the acid that I was then operating upon) and phlogiston; because the union of this acid vapor and phlogiston made inflammable air, and inflammable air, by agitation in water, ceases to be inflammable and becomes respirable. And though I could never make it quite so good as common air, I thought it very probable that vegetation, in more favorable circumstances than any in which I could apply it, or some other natural process, might render it more pure.

Upon this, which no person can say was an improbable supposition, was founded my conjecture of volcanoes having given birth to the atmosphere of this planet, supplying it with a permanent air, first inflammable, then deprived of its inflammability by agitation in water, and farther purified by vegetation.

Several of the known phenomena of the *nitrous acid* might have led me to think that this was more proper for the constitution of the atmosphere than the marine acid; but my thoughts had got into a different train, and nothing but a series of observations, which I shall now distinctly relate, compelled me to adopt another hypothesis, and brought me, in a way of which I had then no idea, to the solution of the great problem, which my reader will perceive I had had in view ever since my discovery that the atmospherical air is alterable, and, therefore, that it is not an elementary substance, but a *composition*, viz., what this composition is, or *what is the thing that we breathe*, and how it is to be made from its constituent principles.

At the time of my former publication I was not possessed of a *burning lens* of any considerable force; and for want of one I could not possibly make many of the experiments that I had projected, and which, in theory, appeared very promising. I had, indeed, a *mirror* of force sufficient for my purpose. But the nature of this instrument is such that it cannot be applied, with effect, except upon substances that are capable of being suspended or resting on a very slender support. It cannot be directed at all upon any substance in the form of *powder*, nor hardly upon anything that requires to be put into a vessel of quicksilver; which appears to me to be the most accurate method of extracting air from a great variety of substances, as was explained in the introduction

to this volume. But having afterwards procured a lens of twelve inches diameter and twenty inches focal distance, I proceeded with great alacrity to examine, by the help of it, what kind of air a great variety of substances, natural and factitious, would yield, putting them into the vessels represented in Fig. *a*, which I filled with quicksilver, and kept inverted in a bason of the same. Mr. Warltire, a good chymist and lecturer in natural philosophy, happening to be at that time in Calne, I explained my views to him, and was furnished by him with many substances, which I could not otherwise have procured.

With this apparatus, after a variety of other experiments, an account of which will be found in its proper place, on the 1st of August, 1774, I endeavored to extract air from *mercurius calcinatus per se;* and I presently found that, by means of this lens, air was expelled from it very readily. Having got about three or four times as much as the bulk of my materials, I admitted water to it, and found that it was not imbibed by it. But what surprized me more than I can well express was that a candle burned in this air with a remarkably vigorous flame, very much like that enlarged flame with which a candle burns in nitrous air exposed to iron or liver of sulphur; but as I had got nothing like this remarkable appearance from any kind of air besides this particular modification of nitrous air, and I knew no nitrous acid was used in the preparation of *mercurius calcinatus*, I was utterly at a loss how to account for it.

In this case, also, though I did not give sufficient attention to the circumstance at that time, the flame of the candle, besides being larger, burned with more splendor and heat than in that species of nitrous air; and a piece of red-hot wood sparkled in it, exactly like paper dipped in a solution of nitre, and it consumed very fast; an experiment which I had never thought of trying with nitrous air.

At the same time that I made the above mentioned experiment, I extracted a quantity of air, with the very same property, from the common *red precipitate*, which being produced by a solution of mercury in spirit of nitre, made me conclude that this peculiar property, being similar to that of the modification of nitrous air above mentioned, depended upon something being communicated to it by the nitrous acid; and since the *mercurius calcinatus* is produced by exposing mercury to a certain degree of heat, where common air has access to it, I likewise concluded that this substance had collected something of *nitre* in that state of heat from the atmosphere.

This, however, appearing to me much more extraordinary than it ought to have done, I entertained some suspicion that the mercurius calcinatus, on which I had made my experiments, being bought at a common apothecary's, might, in fact, be nothing more than red precipitate; though, had I been anything of a practical chymist, I could not

have entertained any such suspicion. However, mentioning this suspicion to Mr. Warltire, he furnished me with some that he had kept for a specimen of the preparation, and which, he told me, he could warrant to be genuine. This being treated in the same manner as the former, only by a longer continuance of heat, I extracted much more air from it than from the other.

This experiment might have satisfied any moderate sceptic; but, however, being at Paris in the October following, and knowing that there were several very eminent chymists in that place, I did not omit the opportunity, by means of my friend, Mr. Magellan, to get an ounce of mercurius calcinatus prepared by Mr. Cadet, of the genuineness of which there could not possibly be any suspicion; and at the same time, I frequently mentioned my surprise at the kind of air which I had got from this preparation to Mr. Lavoisier, Mr. le Roy and several other philosophers, who honored me with their notice in that city; and who, I dare say, cannot fail to recollect the circumstance.

At the same time I had no suspicion that the air which I had got from the mercurius calcinatus was even wholesome, so far was I from knowing what it was that I had really found; taking it for granted that it was nothing more than such kind of air as I had brought nitrous air to be by the processes above mentioned; and in this air I have observed that a candle would burn sometimes quite naturally, and sometimes with a beautiful, enlarged flame, and yet remain perfectly noxious.

At the same time that I had got the air above mentioned from mercurius calcinatus and the red precipitate, I had got the same kind from *red lead* or *minium*. In this process that part of the minium on which the focus of the lens had fallen turned yellow. One third of the air in this experiment was readily absorbed by water; but, in the remainder, a candle burned very strongly and with a crackling noise.

That fixed air is contained in red lead I had observed before, for I had expelled it by the heat of a candle, and had found it to be very pure. (Vol. I., p. 192.) I imagine it requires more heat than I then used to expel any of the other kinds of air.

This experiment with *red lead* confirmed me more in my suspicion that the *mercurius calcinatus* must get the property of yielding this kind of air from the atmosphere, the process by which that preparation and this of red lead is made being similar. As I never make the least secret of anything that I observe, I mentioned this experiment also, as well as those with the mercurius calcinatus and the red precipitate, to all my philosophical acquaintances at Paris and elsewhere, having no idea at that time to what these remarkable facts would lead.

Presently, after my return from abroad, I went to work upon the *mercurius calcinatus* which I had procured from Mr. Cadet, and, with a very moderate degree of heat, I got from about one fourth of an ounce

of it, an ounce-measure of air, which I observed to be not readily imbibed, either by the substance itself from which it had been expelled (for I suffered them to continue a long time together before I transferred the air to any other place) or by water, in which I suffered this air to stand a considerable time before I made any experiment upon it.

In this air, as I had expected, a candle burned with a vivid flame; but what I observed new at this time (Nov. 19), and which surprized me no less than the fact I had discovered before, was that whereas a few moments' agitation in water will deprive the modified nitrous air of its property of admitting a candle to burn in it; yet, after more than ten times as much agitation as would be sufficient to produce this alteration in the nitrous air, no sensible change was produced in this. A candle still burned in it with a strong flame, and it did not in the least diminish common air, which I have observed that nitrous air, in this state, in some measure does.

But I was much more surprized when, after two days, in which this air had continued in contact with water (by which it was diminished about one twentieth of its bulk) I agitated it violently in water about five minutes and found that a candle still burned in it as well as in common air. The same degree of agitation would have made phlogisticated nitrous air fit for respiration indeed, but it would certainly have extinguished a candle.

These facts fully convinced me that there must be a very material difference between the constitution of the air from mercurius calcinatus and that of phlogisticated nitrous air, notwithstanding their resemblance in some particulars. But though I did not doubt that the air from *mercurius calcinatus* was fit for respiration after being agitated in water, as every kind of air without exception on which I had tried the experiment had been, I still did not suspect that it was respirable in the first instance; so far was I from having any idea of this air being what it really was, much superior in this respect to the air of the atmosphere.

In this ignorance of the real nature of this kind of air, I continued from this time (November) to the 1st of March following; having, in the meantime, been intent upon my experiments on the vitriolic acid air, above recited, and the various modifications of air produced by spirit of nitre, an account of which will follow. But in the course of this month I not only ascertained the nature of this kind of air, though very gradually, but was led by it to the complete discovery of the constitution of the air we breathe.

Till this 1st of March, 1775, I had so little suspicion of the air from mercurius calcinatus, etc., being wholesome that I had not even thought of applying to it the test of nitrous air; but thinking (as my reader must imagine I frequently must have done) on the candle burning in it after long agitation in water, it occurred to me at last to make

the experiment; and putting one measure of nitrous air to two measures of this air, I found not only that it was diminished, but that it was diminished quite as much as common air, and that the redness of the mixture was likewise equal to that of a similar mixture of nitrous and common air.

After this I had no doubt but that the air from mercurius calcinatus was fit for respiration, and that it had all the other properties of genuine common air. But I did not take notice of what I might have observed, if I had not been so fully possessed by the notion of there being no air better than common air, that the redness was really deeper, and the diminution something greater than common air would have admitted.

Moreover, this advance in the way of truth, in reality, threw me back into error, making me give up the hypothesis I had first formed, viz., that the mercurius calcinatus had extracted spirit of nitre from the air; for I now concluded that all the constituent parts of the air were equally and in their proper proportion imbibed in the preparation of this substance, and also in the process of making red lead. For at the same time that I made the above mentioned experiment on the air from mercurius calcinatus, I likewise observed that the air which I had extracted from red lead, after the fixed air was washed out of it, was of the same nature, being diminished by nitrous air like common air; but, at the same time, I was puzzled to find that air from the red precipitate was diminished in the same manner, though the process for making this substance is quite different from that of making the two others. But to this circumstance I happened not to give much attention.

I wish my reader be not quite tired with the frequent repetition of the word *surprize*, and others of similar import; but I must go on in that style a little longer. For the next day I was more surprized than ever I had been before with finding that after the above mentioned mixture of nitrous air and the air from mercurius calcinatus had stood all night (in which time the whole diminution must have taken place, and, consequently, had it been common air it must have been made perfectly noxious and entirely unfit for respiration or inflammation) a candle burned in it and even better than in common air.

I cannot at this distance of time recollect what it was that I had in view in making this experiment; but I know I had no expectation of the real issue of it. Having acquired a considerable degree of readiness in making experiments of this kind, a very slight and evanescent motive would be sufficient to induce me to do it. If, however, I had not happened, for some other purpose, to have had a lighted candle before me I should probably never have made the trial, and the whole train of my future experiments relating to this kind of air might have been prevented.

Still, however, having no conception of the real cause of this

phenomenon, I considered it as something very extraordinary; but as a property that was peculiar to air that was extracted from these substances and *adventitious;* and I always spoke of the air to my acquaintance as being substantially the same thing with common air. I particularly remember my telling Dr. Price that I was myself perfectly satisfied of its being common air, as it appeared to be so by the test of nitrous air; though, for the satisfaction of others, I wanted a mouse to make the proof quite complete.

On the 8th of this month I procured a mouse and put it into a glass vessel containing two ounce-measures of the air from mercurius calcinatus. Had it been common air a full-grown mouse, as this was, would have lived in it about a quarter of an hour. In this air, however, my mouse lived a full half hour, and though it was taken out seemingly dead, it appeared to have been only exceedingly chilled; for, upon being held to the fire, it presently revived and appeared not to have received any harm from the experiment.

By this I was confirmed in my conclusion that the air extracted from mercurius calcinatus, etc., was *at least as good* as common air; but I did not certainly conclude that it was any *better;* because, though one mouse would live only a quarter of an hour in a given quantity of air, I knew it was not impossible but that another mouse might have lived in it half an hour, so little accuracy is there in this method of ascertaining the goodness of air; and, indeed, I have never had recourse to it for my own satisfaction since the discovery of that most ready, accurate and elegant test that nitrous air furnishes. But in this case I had a view to publishing the most generally-satisfactory account of my experiments that the nature of the thing would admit of.

This experiment with the mouse, when I had reflected upon it some time, gave me so much suspicion that the air into which I had put it was better than common air, that I was induced, the day after, to apply the test of nitrous air to a small part of that very quantity of air which the mouse had breathed so long; so that, had it been common air, I was satisfied it must have been very nearly, if not altogether, as noxious as possible, so as not to be affected by nitrous air; when, to my surprize again, I found that though it had been breathed so long it was still better than common air. For after mixing it with nitrous air, in the usual proportion of two to one, it was diminished in the proportion of $4\frac{1}{2}$ to $3\frac{1}{2}$; that is, the nitrous air had made it two nnths less than before, and this in a very short space of time; whereas I had never found that in the longest time any common air was reduced more than one fifth of its bulk by any proportion of nitrous air, nor more than one fourth by any phlogistic process whatever. Thinking of this extraordinary fact upon my pillow, the next morning I put another measure of nitrous air to the same mixture, and, to my utter

astonishment, found that it was farther diminished to almost one half of its original quantity. I then put a third measure to it; but this did not diminish it any farther; but, however, left it one measure less than it was even after the mouse had been taken out of it.

Being now fully satisfied that this air, even after the mouse had breathed it half an hour, was much better than common air, and having a quantity of it still left sufficient for the experiment, viz., an ounce measure and a half, I put the mouse into it; when I observed that it seemed to feel no shock upon being put into it, evident signs of which would have been visible if the air had not been very wholesome; but that it remained perfectly at its ease another full half hour, when I took it out quite lively and vigorous. Measuring the air the next day I found it to be reduced from 1½ to 2-3 of an ounce measure. And after this, if I remember well (for in my register of the day I only find it noted that it was considerably diminished by nitrous air) it was nearly as good as common air. It was evident, indeed, from the mouse having been taken out quite vigorous, that the air could not have been rendered very noxious.

For my farther satisfaction I procured another mouse, and putting it into less than two ounce-measures of air extracted from mercurius calcinatus and air from red precipitate (which, having found them to be of the same quality, I had mixed together) it lived three quarters of an hour. But not having had the precaution to set the vessel in a warm place, I suspect that the mouse died of cold. However, as it had lived three times as long as it could probably have lived in the same quantity of common air and I did not expect much accuracy from this kind of test, I did not think it necessary to make any more experiments with mice.

Being now fully satisfied of the superior goodness of this kind of air, I proceeded to measure that degree of purify with as much accuracy as I could, by the test of nitrous air; and I began with putting one measure of nitrous air to two measures of this air, as if I had been examining common air, and now I observed that the diminution was evidently greater than common air would have suffered by the same treatment. A second measure of nitrous air reduced it to two thirds of its original quantity, and a third measure to one half. Suspecting that the diminution could not proceed much farther, I then added only half a measure of nitrous air, by which it was diminished still more; but not much, and another half measure made it more than half of its original quantity; so that, in this case, two measures of this air took more than two measures of nitrous air and yet remained less than half of what it was. Five measures brought it pretty exactly to its original dimensions.

At the same time air from the *red precipitate* was diminished in the same proportion as that from *mercurius calcinatus*, five measures of

nitrous air being received by two measures of this without any increase of dimensions. Now as common air takes about one half of its bulk of nitrous air before it begins to receive any addition to its dimensions from more nitrous air, and this air took more than four half measures before it ceased to be diminished by more nitrous air, and even five half measures made no addition to its original dimensions, I conclude that it was between four and five times as good as common air. It will be seen that I have since procured air better than this, even between five and six times as good as the best common air that I have ever met with.

MEMOIR ON THE EXISTENCE OF AIR IN THE ACID OF NITRE (AND ON THE MEANS OF DECOMPOSING AND RECOMPOSING THIS ACID).*

By ANTOINE-LAURENT LAVOISIER.

I TOOK a small retort with a long narrow neck, which I bent over a lamp so that the end of the neck could be held under a bell-jar full of water standing in a vessel of water. Into the retort I put two ounces of slightly fuming acid of nitre, the weight of which was to that of distilled water in the proportion of 131,607 to 100,000. I added two ounces one dram of mercury and heated it slightly to hasten the solution.

As the acid was very strong, the effervescence was lively and the decomposition very rapid. I received the air which was liberated in different bell-jars in order to be able to tell the differences which might be found between the air at the beginning and at the end of effervescence, supposing there should be such. When the effervescence had stopped and all the mercury had dissolved, I continued to heat the material in the same apparatus. Soon boiling appeared in place of the effervescence, and while the boiling went on air was produced in almost as great abundance as before. I continued this until all the fluid had passed out, either by distillation or as elastic vapors of air, and nothing was left in my retort save a white salt of mercury, in a pasty form, dry rather than wet, which began to grow yellow on its surface. The quantity of air obtained up to this point was about 190 cubic inches; that is to say, about four quarts. All this air was of a uniform sort and was nowise different from what M. Priestley has called nitrous air.

On continuing the experiment, I noticed that from the mercury salt there arose red fumes like those of the acid of nitre; but this phenomenon did not last long and soon the air in the empty part of the retort

* Read before the Paris Academy of Science on April 20, 1776. Translated for THE POPULAR SCIENCE MONTHLY from the 'Comptes Rendus' for the meeting.

regained its transparence.* Having put to one side the air which had been given off during the period of the red fumes, I found ten to twelve inches of air very different from what had been given off up till then, and apparently differing from ordinary air only in that lights burned slightly better in it. At the same time the mercury salt had turned to a fine red precipitate, and, keeping it at a moderate heat, I obtained at the end of seven hours 224 cubic inches of air much purer than ordinary air, in which a light burned with a much brighter, larger and brilliant or more active flame. This air, from all its characteristics, I could not but recognize as the same that I had extracted from calx of mercury, known as mercury *precipitatum per se;* the same that M. Priestley extracted from a number of substances by treating them with spirits of nitre. In proportion as this air had been freed, the mercury had been reduced, and I found again, within a few grains, the two ounces one dram of mercury which I had dissolved. The slight loss may have been due to a little yellow and red sublimate which clung to the upper part of the retort.

The mercury came out of this experiment as it went in, that is, without change in its quality or to any noticeable extent in its weight. So it is evident that the 426 cubic inches of air which I had obtained could have been produced only by the decomposition of the acid of nitre. I was then right in concluding from these facts that two ounces of acid of nitre are composed, first, of 190 cubic inches of nitrous air; second, of 12 cubic inches of ordinary air; third, of 224 cubic inches of air better than ordinary air; fourth, of phlegm; but as it was proved from M. Priestley's experiments, that the small amount of common air which I had obtained could be nothing save air better than common air, the superior quality of which had been altered by mixture with nitrous air in the transition or passing from one to the other, I can determine the amount of these two airs before their mixture and suppose that the 12 cubic inches of common air which I got were due to a mixture of 30 cubic inches of nitrous air and 14 cubic inches of air better than ordinary air.

After thus determining these quantities, we get as the product of two ounces of acid of nitre:

Nitrous air.....	226 cubic inches.
Purest air.....	238 " "
Total.....	464

[Lavoisier here uses the estimated weight of the gases found to decide the composition by weight of nitric acid.]

*These red fumes are due to portions of nitrous air and of air purer than ordinary, which are freed from the mercury salt and which combine and form the acid of nitre. The force of this explanation will be fully felt only after the entire memoir has been read.

Such then is a way to decompose the acid of nitre and demonstrate the existence in it of a pure air and (if I may be allowed to use this expression) more an air than ordinary air. But the complement of the proof was, after having decomposed the acid, to succeed in re-compounding it out of the same materials, and that is what I have done.

[Lavoisier here inserts some preliminary remarks about the nature of nitrous air, and then describes his experiment as follows:]

I filled with water a tube which was closed at one end and which was marked off along its length by equal divisions of volume. I inserted this tube, thus filled with water, in another vessel, likewise filled with water; I let into it seven and one-third parts of nitrous air and mixed with this at the same time four parts of air purer than ordinary air, which I had measured out in another separate tube.* At the moment of mixture, the eleven and a third parts of air occupied 12 to 13 measures, but, a moment later, the two airs mingled and combined, very red vapors of spirits of fuming nitre were formed, which were at once condensed by the water, and in a few seconds the eleven and a third parts of air were reduced to about a third of a measure; that is to say, to about the thirty-fourth part of their original volume.

The water contained in the tube was sensibly acid at the end of this experiment, or, rather, it was a weak acid of nitre; when I treated it with alkali I got from it by evaporation real nitre. . . . After having shown that one can separate and combine again the principles of the acid of nitre, it remains for me to show that the same can be done with materials not all taken from the acid of nitre. Instead of the purest air, or that drawn from the red precipitate of mercury, one may use the air of the atmosphere; but much more of it will have to be used, and instead of the four parts of pure air which are sufficient to saturate seven and one-third parts of nitrous air, one will have to use nearly sixteen of common air; all the nitrous air is, in this experiment, as in the preceding one, destroyed or rather condensed; but this is not the case with common air; not more than a fifth or a fourth of it is absorbed, and what remains is no longer able to support the flame of a candle or to support respiration in animals. It seems proved by this that the air which we breathe contains only a fourth part of real air; that this real air is in our atmosphere mixed with three or four parts of a harmful air, a sort of choke-damp, which would cause the death of the majority of animals if it were present in a little greater quantity. The injurious effects on the air of vapor of charcoal and of a large number of other emanations prove how near this fluid is to the point beyond which it would be fatal to animals. I hope to soon be in a position to discuss this idea and to place before the Academy the experiments on which it is based.

*I pass over the tentative efforts by which I came to know the exact proportion.

It results from the experiments contained in this memoir that when mercury is dissolved in nitric acid, this metallic substance acquires the pure air contained in the nitric acid and constituting it an acid. On the one hand this metal, when combined with the purest air, is reduced to a calx; on the other the acid deprived of this same air expands and forms nitrous air, and the proof that such are the facts in this experiment is that if after having thus separated the two airs which enter into the composition of the acid of nitre, you combine them anew, you make pure acid of nitre such as you had before, with the single difference that it fumes.

The acid of nitre, drawn from saltpetre by clay, is consequently nothing but nitrous air combined with nearly an equal volume of the purest part of the air and with a fairly large amount of water; nitrous air, on the contrary, is the acid of nitre deprived of air and of water. People will no doubt ask here if the phlogiston of the metal does not play some part in this process. Without daring to decide a question of so great importance, I will reply that since the mercury comes out of this experiment just as it went in, there are no signs that it has lost or gained any phlogiston, unless we claim that the phlogiston which brought about the reduction of the metal passed through the vessels. But that is to admit of a particular sort of phlogiston, different from that of Stahl and his school; it is to return to the theory of fire as a principle, to fire as an element of bodies, a theory much older than Stahl's and very different from it.

I will end this memoir as I began it, by thanking M. Priestley, to whom the greater part of whatever interest it possesses is due; but the love of truth and the progress of knowledge, towards which all our efforts should be directed, oblige me at the same time to correct a mistake which he has made, which it would be dangerous to leave unchallenged. This rightly famous physicist, who had discovered that when he combined the acid of nitre with any earth, he invariably obtained ordinary air or air better than ordinary air, believed that he could thence draw the conclusion that the air of the atmosphere is a compound of acid of nitre and of earth. This bold conception is quite overthrown by the experiments contained in this memoir. It is clear that it is not air that is composed of acid of nitre, as M. Priestley claims; but, on the contrary, it is the acid of nitre that is composed of air; and this single remark gives the key to a large number of experiments contained in Sections III., IV. and V. of M. Priestley's second volume.

GENERAL CONSIDERATIONS ON THE NATURE OF ACIDS *

By ANTOINE-LAURENT LAVOISIER.

WHEN the chemists of olden times had reduced a body to oil, salt, earth and water, they believed that they had reached the limits of chemical analysis, and consequently they gave to salt and to oil the names of 'principles of bodies.'

In proportion as the art made progress, the chemists who succeeded them became aware that substances which had been held to be primary could be decomposed, and they recognized in succession that all the neutral salts, for instance, were formed by the union of two substances, an acid of some sort and a salt, earth or metal.

Hence arose the entire theory of neutral salts which has held the attention of chemists for over a century, and which is to-day so near perfection that we may regard it as the surest and most complete part of chemistry.

Chemical science has been handed down to us in this condition, and it is our business to do with the constituents of the neutral salts what the chemists who went before us did with the neutral salts themselves, to attack the acids and bases and to carry chemical analysis along this line a step beyond its present limits.

I have already imparted to the Academy my first efforts in this field. I have in earlier memoirs demonstrated to you as far as it is possible to demonstrate in physics and chemistry that the purest air, that to which M. Priestley has given the name of 'dephlogisticated air,' enters as a constituent part into the composition of several acids, notably of phosphoric, vitriolic and nitric acids.

More numerous experiments put me in a position to-day to draw general conclusions from these results and to assert that the purest air, the air most suitable for respiration, is the principle which causes acidity; that this principle is common to all acids, and that in addition one or more other principles enter into the composition of each acid, differentiating it and making it one sort of acid rather than another.

In consequence of these facts, which I already regard as very firmly established, I shall henceforth call dephlogisticated air or air most suitable for respiration, when it is in a state of combination or fixity, by the name of 'the acidifying principle,' or, if one prefers the same meaning in a word from the Greek, 'the principle *Oxygine*.' This nomenclature will save periphrases, will make my statements more exact, and will avoid the ambiguities I would be likely to fall into constantly if I used the word 'air.'

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* Read before the Paris Academy of Sciences on September 5, 1777. Translated for THE POPULAR SCIENCE MONTHLY from the 'Comptes Rendus' for the meeting.

Without repeating details which I have given elsewhere, I will recall herein a few words, adopting this new language:

1. That the acidifying principle or oxygen, when combined with the substance of fire, heat and light, forms the purest air, that which M. Priestley has called dephlogisticated air; it is true that this first proposition is not strictly proved and perhaps is not susceptible of strict proof; so I have proposed it only as an idea that I regard as very probable, and in that respect it must not be confused with the propositions which are to follow, which are based on rigorous experiments and proofs;

2. That this same acidifying principle or oxygen, combined with carbon or substances containing carbon, forms the acid of chalk (carbonic acid) or fixed air;

3. That with sulphur it forms vitriolic acid;

4. That with nitrous air it forms nitric acid;

5. That with Kunckel's phosphorus it forms phosphoric acid;

6. That with metallic substances in general it forms metallic calces, with the exception of the cases of which I shall speak in this or a following memoir.

Such is very nearly our present general knowledge of the combinations of oxygen with the different substances in nature, and it is not hard to see that there remains a vast field to explore; that there is a part of chemistry absolutely new and until now unknown, which will be completely investigated only when we shall have succeeded in determining the degree of affinity of this principle with all the substances with which it can combine, and in discovering the different sorts of compounds which result.

All chemists know that the simpler the substances are with which you are working, the nearer you come to reducing substances to their elementary molecules, the more difficult become the means of decomposing and recomposing the substances; we may suppose, therefore, that the analysis and synthesis of acids must present much greater difficulties than does the analysis of the neutral salts into the composition of which they enter. I hope, however, to be able in what follows to show that there is no acid, unless, perhaps, it be that of sea salt, which we cannot analyze and put together again and from which we cannot at will abstract the acidifying principle.

This kind of work demands a great variety of means, and the procedures necessary to success in effecting combination vary according to the different substances with which one is working. In some cases we must have recourse to combustion, either in atmospheric air or pure air. Such is the case with sulphur, phosphorus and carbon; these substances during combustion absorb the acidifying principle or oxygen, and by the addition of this principle become vitriolic, phosphoric and carbonic acid or fixed air.

In the case of other substances mere exposure to the air, aided by a moderate degree of heat, suffices to bring about the combination, and this is what happens to all vegetable substances capable of passing on to acid fermentation. In the greater number of cases one has to resort to the science of affinities and to employ the acidifying principle already united in another compound.

The example which I am going to give to-day is of this last sort, and I shall take it from an experiment, well known for several years, following the memoirs of M. Bergman. It is the formation of the acid of sugar. This acid, in accordance with the experiments which I am going to recount, seems to me to be nothing else than sugar combined with the acidifying principle or oxygen, and I propose to show in order in different memoirs that we can combine this same principle with the substance composing animals' horns, with silk, with animal lymph, with wax, with essential oils, with extracted oils, manna, starch, arsenic, iron and probably with a great many other substances of the three kingdoms. We can thus turn all these substances into genuine acids.

Before entering on the material to be presented, I beg the Academy to recall that the acid of nitre, as shown by the experiments which I have before described, and which I have repeated in your presence, is the result of the union of nitrous air with the purest air or acidifying principle; that the proportion of these two principles varies in the different kinds of acid of nitre, the one which gives off fumes, for instance, containing a superabundance of nitrous air.

CHAPTERS ON THE STARS.

By Professor SIMON NEWCOMB, U. S. N.

Masses and Densities of the Stars.

THE spectroscope shows that, although the constitution of the stars offers an infinite variety of detail, we may say, in a general way, that these bodies are suns. It would perhaps be more correct to say that the Sun is one of the stars and does not differ essentially from them in its constitution. The problem of the physical constitution of the Sun and stars may, therefore, be regarded as the same. Both consist of vast masses of incandescent matter at so exalted a temperature as to shine by their own light. All may be regarded as bodies of the same general nature.

It has long been known that the mean density of the Sun is only one-fourth that of the earth, and, therefore, less than half as much again as that of water. In a few cases an approximate estimate of the density of stars may be made. The method by which this may be done can be rigorously set forth only by the use of algebraic formulæ, but a general idea of it can be obtained without the use of that mode of expression.

Let us in advance set forth an extension of Kepler's third law, which applies to every case of two bodies revolving around each other by their mutual gravitation. The law in question, as stated by Kepler, is that the cubes of the mean distances of the planets are proportioned to the squares of their times of revolution. If we suppose the mean distances to be expressed in terms of the earth's mean distance from the Sun as a unit of length, and if we take the year as the unit of time, then the law may be expressed by saying that the cubes of the mean distances will be equal to the squares of the periods. For example, the mean distance of Jupiter is thus expressed as 5.2. If we take the cube of this, which is about 140, and then extract the square root of it, we shall have 11.8, which is the period of revolution of Jupiter around the Sun expressed in the same way. If we cube 9.5, the mean distance of Saturn, we shall have the square of a little more than 29, which is Saturn's time of revolution.

We may also express the law by saying that if we divide the cube of the mean distance of any planet by the square of its periodic time we shall always get 1 as a quotient.

The theory of gravitation and the elementary principles of force and motion show that a similar rule is true in the case of any two bodies revolving around each other in virtue of their mutual gravitation. If

we divide the cube of their mean distance apart by the square of their time of revolution, we shall get a quotient which will not indeed be 1, but which will be a number expressing the combined mass of the two bodies. If one body is so small that we leave its mass out of consideration, then the quotient will express the mass of the larger body. If the latter has several minute satellites moving around it, the quotients will be equal, as in the case of the Sun, and will express the mass of this central body. If, as in the case we have supposed, we take the year as a unit of time and the distance of the earth from the Sun as a unit of length, the quotient will express the mass of the central body in terms of the mass of the Sun. It is thus that the masses of the planets are determined from the periodic times and distances of their satellites,

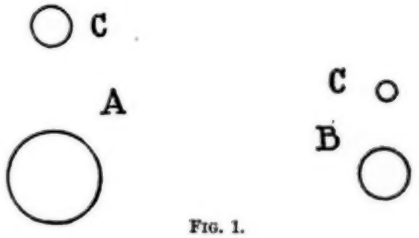

FIG. 1.

and the masses of binary systems from their mean distance apart and their periods. To express the general law by a formula we put

a, the mean distance apart of the two bodies, or the semi-major axis of their relative orbit in terms of the earth's mean distance from the Sun;

P, their periodic time;

M, their combined mass in terms of the Sun's mass as unity.

Then we shall have:

$$M = \frac{a^3}{P^2}$$

Another conclusion we draw is that if we know the time of revolution and the radius of the orbit of a binary system, we can determine what the time of revolution would be if the radius of the orbit had some standard length, say unity.

We cannot determine the dimensions of a binary system unless we know its parallax. But there is a remarkable law which, so far as I know, was first announced by Pickering, by virtue of which we can determine a certain relation between the surface brilliancy and the density of a binary system without knowing its parallax.

Let us suppose a number of bodies of the same constitution and temperature as the Sun—models of the latter we may say—differing from it only in size. To fix the ideas, we shall suppose two such bodies, one having twice the diameter of the other. Being of the same brilliancy, we suppose them to emit the same amount of light per unit of

surface. The larger body, having four times the surface of the smaller, will then emit four times as much light. The volumes being proportional to the cubes of their diameters, it will have eight times its volume. The densities being supposed equal, it will have eight times the mass. Suppose that each has a satellite revolving around it, and that the orbit of the satellite of the larger body is twice the radius of that of the smaller one.

Calling the radius of the nearer satellite 1, that of the more distant one will be 2. The cube of this number is 8. It follows from the extension of Kepler's third law, which we have cited, that the times of revolution of the two satellites will be the same. Thus the two bodies, A and B, with their satellites, C and C, form two binary systems whose proportions and whose periods are the same, only the linear dimensions of B are all double those of A. In other words, we shall have a pair of binary systems which may look alike in every respect, but of which one will have double the dimensions and eight times the mass of the other.

Now let us suppose the larger system to be placed at twice the distance of the smaller. The two will then appear of the same size, and, if stars, will appear of the same brightness, while the two orbits will have the same apparent dimensions. In a word, the two systems will appear alike when examined with the telescope, and the periodic times will be equal.

Near the end of the second chapter we have given a little table showing the magnitude that the Sun would appear to us to have were it placed at different distances among the stars. The parallaxes we have there given are simply the apparent angle which would have to be subtended by the radius of the earth's orbit at different distances. It follows that, were the stars all of similar constitution to the Sun, the numbers given in the last column of the table referred to would, in all cases, express the apparent distance from the star of a companion, having a time of revolution of one year. From this we may easily show what would be the time of revolution of any binary system of which the companions were separated by 1″, if the stars were of the same constitution as the Sun.

Periods of binary systems whose components are separated by 1″ and whose constitution is the same as that of the Sun.

Mag.	Period. y.	Annual Motion.
1	1.8	200°
2	3.5	102
3	7.0	51
4	14.1	25
5	28.1	13
6	56.0	6
7	112.	3.2
8	223.	1.6

It will be seen that the periods are very nearly doubled for each diminution of the brilliancy of the star by one magnitude. Moreover, the value of the photometric ratio for two consecutive magnitudes is a little uncertain, so that we may, without adding to the error of our results, suppose the period to be exactly double for each addition of unity to the magnitude. A computation of the period for any magnitude may be made with all necessary precision by the formula:

$$P = 0^{y}.88 \times 2^{m};$$
$$\text{or,} \quad \log. P = 9.994 + 0.3m.$$

It will now be of interest to compare the results of this theory with the observed periods of binary systems with a view to comparing their constitution with that of our Sun. There are, however, two difficulties in the way of doing this with rigorous precision.

The first difficulty is that there are very few binary systems of which the apparent dimensions of the orbit and the periods are known with any approach to exactness. This would not be a serious matter were it not that the short, and, therefore, known periods belong to a special class, that having the greatest density. Hence, when we derive our results from the systems of known periods we shall be making a biased selection from this particular class of stars.

The next difficulty is that the theory which we have set forth assumes the mass of the satellite either to be very small compared with that of the star, or the two bodies to be of the same constitution. If we apply the theory to systems in which this is not the case, the results which we shall get will be, in a certain way, those corresponding to the mean of the two components. Were it a question of masses, we should get with entire precision the sum of the masses of the two bodies. The best we can do, therefore, is to suppose the two companions fused into one having the combined brilliancy of the two. Then, if the result is too small for one, it will be too large for the other.

To show the method of proceeding, I have taken the six systems of shortest period found in Dr. See's 'Researches on Stellar Evolution.' The principal numbers are shown in the table below.

The first column, a'', after the name of the star, gives the apparent semi-major axis of the orbit in seconds of arc. The next column gives the period in years. Column Mag. gives the apparent magnitude which the system would have were the two bodies fused into one.

Column P gives the period in years as it would be were the radius of the orbit equal to one second. It is formed by dividing the actual period by A. The next column gives the period as it would be were the stars of similar constitution to the Sun. The last column gives the square of the ratio of the two bodies, which, if the stars had the same

surface brilliancy as the Sun, would express the ratio of density of the stars to that of the Sun. Actually, it gives the product:

$$\text{Density} \times (\text{brilliancy})^{\frac{1}{2}}.$$

	a."	Per.	Mag.	P.	Sun's Per.	Star's Density.
κ Pegasi	0".42	11y.4	4.2	41.9	16.2	0.15
ζ Equulei	0".45	11y.4	4.6	37.8	21.0	0.31
ξ Sagittarii	0".69	18y.8	2.9	32.7	6.7	0.04
F9 Argus	0".65	22y.0	5.5	42.0	39.7	0.90
42 Cornæ	0".64	25y.6	4.4	50.0	18.5	0.14
β Delphirii	0".67	27y.7	3.7	50.4	11.4	0.51

The numbers in the last column being all less than unity, it follows that either the stars are much less dense than the Sun or they are of much less surface brilliancy. Moreover, they belong to a selected list in which the numbers of the last column are larger than the average.

To form some idea of the result of a selection from the general average, we may assume that the average of all the measured distances between the components of a number of binary systems is equal to the average radius of their orbits, and that the observed annual motion is equal to the mean motion of the companion in its orbit. Taking a number of cases of this sort, I find that the number corresponding to the last number of the preceding table would be little more than one thousandth.

A very remarkable case is that of ξ Orionis. This star, in the belt of Orion, is of the second magnitude. It has a minute companion at a distance of 2".5. Were it a model of the Sun, a companion at this apparent distance should perform its revolution in fourteen years. But, as a matter of fact, the motion is so slow that even now, after fifty years of observation, it cannot be determined with any precision. It is probably less than 0°.1 in a year. The number expressing the comparison of its density and surface brilliancy with those of the Sun is probably less than .0001.

The general conclusion to be drawn is obvious. The stars in general are not models of our Sun, but have a much smaller mass in proportion to the light they give than our Sun has. They must, therefore, have either a less density or a greater surface brilliancy.

We may now inquire whether such extreme differences of surface brilliancy or of density are more likely. The brilliancy of a star depends primarily not on its temperature throughout, but on that of some region near or upon its surface. The temperature of this surface cannot be kept up except by continual convection currents from the interior to the surface. We are, therefore, to regard the amount of light

emitted by a star not merely as indicating temperature, but as limited by the quantity of matter which, impeded by friction, can come up to the surface, and there cool off and afterward sink down again. This again depends very largely on internal friction, and is limited by that. Owing to this limitation, we cannot attribute the difference in question wholly to surface brilliancy. We must conclude that at least the brighter stars are, in general, composed of matter much less dense than that of the Sun. Many of them are probably even less dense than air and in nearly all cases the density is far less than that of any known liquid.

An ingenious application of the mechanical principle we have laid down has been made independently by Mr. Roberts, of South Africa, and Mr. Norris, of Princeton, in another way. If we only knew the relation between the diameters of the two companions of a binary system and its dimensions, we could decide how much of the difference in question is due to density and how much to surface brilliancy. Now this may be approximately done in the case of variable stars of the Algol and β Lyræ types. If, as is probably the most common case, the passage of the stars over each other is nearly central, the ratio of their diameter to the radius of the orbit may be determined by comparing the duration of the eclipse with the time of revolution. This was one of the fundamental data used by Myers in his work on β Lyræ, of which we have quoted the results. Without going into reasoning or technical details at length, we may give the results reached by Roberts and Norris in the case of the Algol variables:

For the variable star X Carinæ, Roberts finds, as a superior limit for the density of the star and its companion, one-fourth that of the Sun. It may be less than this is, to any extent.

In the case of S Velorum the superior limits of density are:

Bright star	0.61
Companion	0.03

In the case of RS Sagittarii the upper limits of density are 0.16 and 0.21.

It is possible, in the mean of a number of cases like these, to estimate the general average amount by which the densities fall below the limits here given. Roberts' final conclusion is that the average density of the Algol variables and their eclipsing companions is about one eighth that of the Sun.

The work of Russell was carried through at the same time as that of Roberts, and quite independently of his. It appeared at the same time.* His formulæ and methods were different, though they rested on similar fundamental principles. Taking the density of the Sun as

* 'Astrophysical Journal,' Vol. X, No. 5.

unity, he computes the superior limit of density for 12 variables, based on their periods and the duration of their partial eclipses. The greatest limit is in the case of Z Herculis and is 0.728. The least is in the case of S Caneri and is 0.035. The average is about 0.2. As the actual density may be less than the limit by an indefinite amount, the general conclusion from his work may be regarded as the same with that from the work of Roberts.

The results of the preceding theory are independent of the parallax of the stars. They, therefore, give us no knowledge as to the mass of a binary system. To determine this we must know its parallax, from which we can determine the actual dimensions of the orbit when its apparent dimensions are known. Then the formula already given will give the actual mass of the system in terms of the Sun's mass.

There are only six binary systems of which both the orbit and the parallax are known. These are shown in the table below. Here the first two columns after the stars named give the semi-major axis of the orbit and the measured parallax. The quotient of the first number by the second gives the actual mean radius of the orbits in terms of the earth's distance from the Sun as unity. This is given in the third column, after which follow the period and the resulting combined mass of the system. The last column shows the actual amount of light emitted by the system, compared with that of the Sun.

	a."	Par.	a.	Period.	Mass.	Light.
	"	"		y.		
η Cassiopiæ	8.21	0.20	41.0	195.8	1.8	1.0
Sirius	8.03	0.37	21.7	52.2	3.7	32.0
Procyon	3.00	0.30	10.0	40.0	0.6	8.5
α Centauri	17.70	0.75	23.6	81.1	2.0	1.7
70 Ophiuchi	4.55	0.19	24.0	88.4	1.8	0.7
85 Pegasi	0.89	0.05	17.8	24.0	9.0	2.2

Even in these few cases some of the numbers on which the result depends are extremely uncertain. In the case of Procyon, the radius of the orbit can be only a rough estimate. In the case of 85 Pegasi the parallax is uncertain. In the case of η Cassiopiæ the elements are still doubtful.

So far as we have set forth the principles involved in the question, we do not get separate results for the mass of each body. The latter can be determined only by meridian observations, showing the motion of the brighter star around the common center of gravity of the two. This result has thus far been worked out with an approximation to exactness only in the cases of Sirius and Procyon. For these systems we have the following masses of the companions of these bodies in terms of the Sun's mass:

Companion of Sirius	1.2
Companion of Procyon	0.2

It will now be interesting to compare the brightness of these bodies with that which the Sun would have if seen at their distance. In a former chapter we showed how this could be done. The results are:

At the distance of Procyon the apparent magnitude of the Sun would be $2^m.8$. At the distance of Sirius, it would be $2^m.3$. Supposing the Sun to be changed in size, its density remaining unchanged, until it had the same mass as the respective companions of Procyon and Sirius, its magnitudes would be:

For companion of Procyon	3.9
For companion of Sirius	2.9

The actual magnitudes of these companions cannot be estimated with great precision, owing to the effect of the brilliancy of the star. From the estimate of the companion of Sirius, by Professor Pickering, its magnitude was about the eighth. It is probable that the magnitude of the companion of Procyon is not very different. It will be seen that these magnitudes are very different from those which they would have were the companions models of the Sun. What is very curious is that they differ in the opposite direction from the stars in general, and especially from their primaries. Either they have a far less surface brilliancy than the Sun or their density is much greater. There can be no doubt that the former rather than the latter is the case.

This great mass of the two companions as compared with their brilliancy suggests the question whether they may not shine, in part at least, by the light of their primaries. A very little consideration will show that this cannot be the case. A simple calculation will show that, to shine as brightly as they do, the diameter of the companion of Sirius would have to be enormous, at least 1-30 its distance from Sirius. Moreover, its apparent brightness would vary so widely in different parts of its orbit that we should see it almost as well when near Sirius as when distant from it. The most likely cause of the small brightness is the low temperature of the body.

Gaseous Constitution of the Stars.

The results of the last chapter point to the conclusion that the stars, or at least the brighter among them, are masses of gas, more or less compressed in their interior by the action of gravitation upon their more superficial parts. We have now to show how this result was arrived at, at least in the case of the Sun, from different considerations, before the spectroscope had taught us anything of the constitution of these bodies.

We must accept, as one of the obvious conclusions of modern science,

the fact that the Sun and stars have, for untold millions of years, been radiating heat into space. If we refrain from considering the basis on which this conclusion rests, it is not so much because we consider it unquestionable, as because the discussion would be too long and complex for the present work.

One of the great problems of modern science has been to account for the source of this heat. Before the theory of energy was developed this problem offered no difficulty. In the time of Newton, Kant and even of La Place and Herschel, no reason was known why the stars should not shine forever without change. Now we know that when a body radiates heat, that heat is really an entity termed *energy*, of which the supply is necessarily limited. Kelvin compared the case of a star radiating heat with that of a ship of war belching forth shells from her batteries. We know that if the firing is kept up, the supply of ammunition must at some time be exhausted. Have we any means of determining how long the store of energy in Sun or star will suffice for its radiation?

We know that the substances which mainly compose the Sun and stars are similar to those which compose our earth. We know the capacity for heat of these substances, and we also have determined how much the Sun radiates annually. From these data, it is found by a simple calculation that the temperature of the Sun would be lowered annually by more than two degrees Fahrenheit, if its capacity for heat were the same as that of water. If this capacity were only that of the substances which compose the great body of the earth, the lowering of temperature would be from 5° to 10° annually. Evidently, therefore, the actual heat of the Sun would only suffice for a few thousand years' radiation, if not in some way replenished.

When the difficulty was first attacked, it was supposed that the supply might be kept up by meteors falling into the Sun. We know that in the region round the Sun, and, in fact, in the whole Solar System, are countless minute meteors some of which may from time to time strike the Sun. The amount of heat that would be produced by the loss of energy suffered by a meteor moving many hundred miles a second would be enormously greater than that which would be produced by combustion. But critical examination shows that this theory cannot have any possible basis. Apart from the fact that it could at best be only a temporary device there seems to be no possibility that meteors sufficient in mass can move round the Sun or fall into it. Shooting stars show that our earth encounters millions of little meteors every day; but the heat produced is absolutely insignificant.

It was then shown by Kelvin and Helmholtz that the Sun might radiate the present amount of heat for several millions of years, simply from the fund of energy collected by the contraction of its volume

through the mutual gravitation of its parts. As the Sun cools it contracts; the fall of its substance toward the center, produced by this contraction, generates energy, which energy is constantly turned into heat. The amount of contraction necessary to keep up the present supply may be roughly computed; it amounts in round numbers to 220 feet a year, or four miles in a century.

Accepting this view, it will almost necessarily follow that the great body of the Sun must be of gaseous constitution. Were it solid, its surface would rapidly cool off, since the heat radiated would have to be conducted from the interior. Then, the loss of heat no longer going on at the same rate, the contraction also would stop and the generation of heat to supply the radiation would cease. Even were the Sun a liquid, currents of liquid matter could scarcely convey to the surface a sufficient amount of heated matter to supply the enormous radiation. Thus the reason of the case combines with observation of the density of the Sun to show that its interior must be regarded as gaseous rather than solid or liquid.

A difficult matter, however, presents itself. The density of the Sun is greater than we ordinarily see in gases, being, as we have remarked, even greater than the density of water. The explanation of this difficulty is very simple: the gaseous interior is subject to compression by its superficial portions. The gravitation on the surface being 27 times what it is on the earth, the pressure increases 27 times as fast when we go toward the center as it does on the earth. We should not have to go very far within its body to find a pressure of millions of tons on the square inch. Under such pressure and at such an enormous temperature as must there prevail, the distinction between a gas and a liquid is lost; the substance retains the mobility of a gas, while assuming the density of a liquid.

It does not follow, however, that the visible surface of the Sun is a gas, pure and simple. The sudden cooling which a mass of gaseous matter undergoes on reaching the surface may liquefy it or even change it into a solid. But, in either case, the sudden contraction which it thus undergoes makes it heavier and it sinks down again to be remelted in the great furnace below. It may well be, therefore, that the description of the Sun as a vast bubble is nearly true. It may be added that all we have said about the Sun may very well be presumed to apply to the stars. We have now to consider the law of change as a sun or star contracts through the loss of heat suffered by its radiation into space.

This subject was very exhaustively developed by Ritter some years since.* It is not practicable to give even an abstract of Ritter's results at the present time, especially as every mathematical investigation of the subject must either rest on hypotheses more or less uncertain, or

* Wiedemann's 'Annalen der Physik u. Chemie,' 1878 to 1883, etc.

must, for its application, require data impossible to obtain. We shall, therefore, confine ourselves to a brief outline of the main points of the subject. A fundamental proposition of the whole theory is Lane's law of gaseous attraction, which is as follows:

When a spherical mass of incandescent gas contracts through the loss of its heat by radiation into space, its temperature continually becomes higher as long as the gaseous condition is retained.

The demonstration of this law is simple enough to be understood by any one well acquainted with elementary mechanics and physics, and it will also furnish the basis for our consideration of the subject.

We begin by some considerations on the condition of a mass of gas held together by the mutual attraction of its parts. This attraction results in a certain hydrostatic pressure, capable of being expressed as so many pounds or tons per unit of surface, say a square inch. This pressure at any point is equal to the weight of a column of the gas, having a section of one square inch and extending from the point in

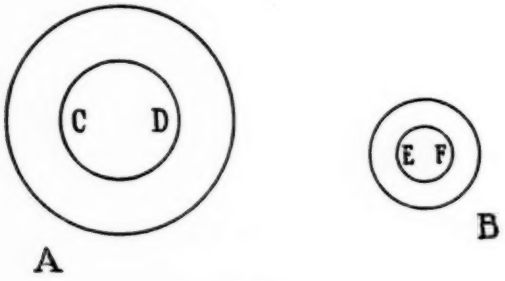

FIG. 2.

question to the surface. It is a law of attraction in a sphere of which the density is the same at equal distances from its center, that if we suppose an interior sphere concentric with the body, the attraction of all the matter outside that interior sphere, on any point within it, is equal in every direction, and, therefore, is completely neutralized. A point is, therefore, drawn towards the center only by the attraction of the sphere on the surface of which it lies.

At every point in the interior the hydrostatic pressure must be balanced by the elastic force of the gas. In the case of any one gas this force is proportional to the product of the density into the absolute temperature. This condition of equilibrium must be satisfied at every point throughout the mass.

Let the two circles in the figure represent gaseous globes, of the kind supposed. The larger one represents the globe in a certain condition of its evolution; the second its condition after its volume has contracted to one half. The temperature in each case will necessarily

increase from the surface to the center. The law of this increase is incapable of accurate expression, but is not necessary for our present purpose.

Let the inner circle, C D, represent a spherical shell, situated anywhere in the interior of the mass, but concentric with it. Let E F be the corresponding shell after the contraction has taken place. The case will then be as follows:

The two shells will by hypothesis have the same quantity of matter, both in their own substance and throughout their interior.

In case B the central attraction being as the inverse square from the center, will be four times as great for each unit of matter in the shell.

This force of attraction, tending to compress the shell, is, in case B, exerted on a surface one quarter as great, because the surface of a shell is proportional to the square of its diameter.

Hence the hydrostatic pressure per unit of surface is 16 times as great in case B as in case A.

The elastic force of a gas, if the two bodies were at the same temperature, would be 8 times as great in case B as in case A, being inversely as the volume.

The hydrostatic pressure being 16 times as great, while the elastic force to counterbalance it is only 8 times as great, no equilibrium would be possible. To make it possible, the absolute temperature of the gas must be doubled, in order that the elastic force shall balance the pressure.

That a mass can become hotter through cooling, may, at first sight, seem paradoxical. We shall, therefore, cite a result which is strictly analogous. If the motion of a comet is hindered by a resisting medium, the comet will continually move faster. The reason of this is that the first effect of the medium is to diminish the velocity of the object. Through this diminution of velocity, the comet falls towards the Sun. The increase of velocity caused by the fall more than counterbalances the diminution produced by the resistance. The result is that the comet takes up a more and more rapid motion, as it gradually approaches the Sun, in consequence of the resistance it suffers. In the same way, when a gaseous celestial body cools, the fall of its mass towards the center changes from a potential to an actual form an amount of energy greater than that radiated away.

The critical reader will see a weak point in this reasoning, which it is necessary to consider. What we have really shown is that if the mass, assumed to be in a state of equilibrium when it has the size A, has to remain in equilibrium when it has the size B, then its temperature must be doubled. But we have not proved that its temperature actually will be doubled by the fall. In fact, it cannot be doubled unless the

energy generated by the fall of the superficial portions towards the center is sufficient to double the absolute amount of heat. Whether this will be the case depends on a variety of circumstances; the mass of the whole body, and the capacity of its substance for heat. If we are to proceed with mathematical rigor, it is, therefore, necessary to determine in any given case whether this condition is fulfilled. Let us suppose that in any particular case the mass is so small or the capacity for heat so considerable that the temperature is not doubled by the contraction. Then the contraction will go on further and further, until the mass becomes a solid. But in this case let us reverse the process. The body being supposed nearly in a state of equilibrium in position A, let the elastic force be slightly in excess. Then the gas will expand. In order that it be reduced to a state of equilibrium by expansion, its temperature must diminish according to the same law that it would increase if it contracted. When its diameter doubles, its temperature should be reduced to one half or less by the expansion, in order that the equilibrium shall subsist. But, in the case supposed, the temperature is not reduced so much as this. Hence, it is too high for equilibrium by a still greater amount and the expansion must go on indefinitely. Thus, in the case supposed, the hypothetical equilibrium of the body is unstable. In other words, no such body is possible.

This conclusion is of fundamental importance. It shows that the possible mass of a star must have an inferior limit, depending on the quantity of matter it contains, its elasticity under given circumstances and its capacity for heat. It is certain that any small mass of gas, taken into celestial space and left to itself, would not be kept together by the mutual attraction of its parts, but would merely expand into indefinite space. Probably this might be true of the earth, if it were gaseous. The computation would not be a difficult one to make, but I have not made it.

In what precedes, we have supposed a single mass to contract. But our study of the relations of temperature and pressure in the two masses assumes no relationship between them, except that of equality. Let us now consider any two gaseous bodies, A and B, and suppose that the body B, instead of having the same mass as that of A, is another body with a different mass.

Since the mass, B, may be of various sizes, according to the amount of attraction it has undergone, let us begin by supposing it to have the same volume as A, but twice the mass of A. We have then to inquire what must be its temperature in order that it may be in equilibrium. We have first to inquire into the hydrostatic pressure at any point of the interior. Referring once more to a figure like either of those in Fig. 2, a spherical shell like C D will now in the case of the more massive body have double the mass of the corresponding shell of A. The

attraction will also be doubled, because the diameter of the spherical shell is the same, while the amount of matter within it is twice as great. Hence the hydrostatic pressure per unit of surface will be four times as great, or will vary as the square of the density. The elasticity at equal temperatures being proportional to the density, it follows that were the temperature the same in the two masses, the elasticity would be double in the case of mass B; whereas, to balance the hydrostatic pressure it should be quadrupled. The temperature of B must, therefore, be twice as great as that of A. It follows that in the case of stars of equal volume, but of different masses, the temperature must be proportional to the mass of density.

But how will it be if we suppose the density to be always the same, and, therefore, the mass to be proportional to the volume? In this case the attraction at a given point will be proportional to the diameter of the body. If, then, we suppose one body to have twice the diameter of the other, but to be of the same density, it follows that at corresponding points of the interior, the hydrostatic pressure will be twice as great in the larger body. The density being the same, it follows that the temperature must be twice as high in order that equilibrium may be maintained. It follows that the stars of the greatest mass will be at the highest temperature, unless their volume is so great that their density is less than that of the smaller stars.

Stellar Evolution.

It follows from the theory set forth in the last chapter that the stars are not of fixed constitution, but are all going through a progressive change—cooling off and contracting into a smaller volume. If we accept this result, we find ourselves face to face with an unsolvable enigma—how did the evolution of the stars begin? To show the principle involved in the question, I shall make use of an illustration drawn from a former work.* An inquiring person wandering around in what he supposes to be a deserted building, finds a clock running. If he knows nothing about the construction of the clock, or the force necessary to keep it in motion, he may fancy that it has been running for an indefinite time just as he sees it, and that it will continue to run until the material of which it is made shall wear out. But if he is acquainted with the laws of mechanics, he will know that this is impossible, because the continued movement of the pendulum involves a constant expenditure of energy. If he studies the construction of the clock, he will find the source of this energy in the slow falling of a weight suspended by a cord which acts upon a train of wheels. Watching the motions, he will see that the scape wheel acting on the pendulum

* 'Popular Astronomy,' by Simon Newcomb; Harper & Bros., New York.

moves very perceptibly every second, while he must watch the next wheel for several seconds to see any motion. If the time at his disposal is limited, he will not be able to see any motion at all in the weight. But an examination of the machinery will show him that the weight must be falling at a certain rate, and he can compute that, at the end of a certain time, the weight will reach the bottom, and the clock will stop. He can also see that there must have been a point from above which the weight could never have fallen. Knowing the rate of fall, he can compute how long the weight occupied in falling from this point. His final conclusion will be that the clock must in some way have been wound up and set in motion a certain number of hours or days before his inspection.

If the theory that the heat of the stars is kept up by their slow contraction is accepted, we can, by a similar process to this, compute that these bodies must have been larger in former times, and that there must have been some finite and computable period when they were all nebulæ. Not even a nebula can give light without a progressive change of some sort. Hence, within a certain finite period the nebulæ themselves must have begun to shine. How did they begin? This is the unsolvable question.

The process of stellar evolution may be discussed without considering this question. Accepting as a fact, or at least as a working hypothesis, that the stars are contracting, we find a remarkable consistency in the results. Year by year laws are established and more definite conclusions reached. It is now possible to speak of the respective ages of stars as they go through their progressive course of changes. This subject has been so profoundly studied and so fully developed by Sir William and Lady Huggins that I shall depend largely on their work in briefly developing the subject.*

At the same time, in an attempt to condense the substance of many folio pages into so short a space, one can hardly hope to be entirely successful in giving merely the views of the original author. The following may, therefore, be regarded as the views of Sir William Huggins, condensed and arranged in the order in which they present themselves to the writer's mind.

There is an infinite diversity among the spectra of the stars; scarcely two are exactly alike in all their details. But the larger number of these spectra, when carefully compared, may be made to fall in line, thus forming a series in which the passage of one spectrum into the next in order is so gradual as to indicate that the actual differences represent, in the main, successive epochs of star life rather than so many fundamental differences of chemical constitution. Each star may be considered to go through a series of changes analogous to those of a human

* Publications of Sir William Huggins's Observatory, Vol. I; London, 1899.

being from birth to old age. In its infancy a star is simply a nebulous mass; it gradually condenses into a smaller volume, growing hotter, as set forth in the last chapter, until a stage of maximum temperature is reached, when it begins to cool off. Of the duration of its life we cannot form an accurate estimate. We can only say that it is to be reckoned by millions, tens of millions or hundreds of millions of years. We thus view in the heavens stars ranging through the whole series from the earliest infancy to old age. How shall we distinguish the order of development? Mainly by their colors and their spectra. In its first stage the star is of a bluish white. It gradually passes through white into yellow and red. Sir William gives the following series of stars as an example of the successive orders of development:

Sirius, α Lyræ.
α Ursæ Majoris.
α Virginis.
α Aquilæ.
Rigel.
α Cygni.
. . .
Capella—**The Sun.**
Arcturus.
Aldebaran.
α Orionis.

The length of the life of a star has no fixed limit; it depends entirely on the mass. The larger the mass, the longer the life; hence a small star may pass from infancy to old age many times more rapidly than a large one.

A remarkable confirmation of this order is found in the generally yellow or red color of the companions of bright stars in binary systems. The two stars of such a system naturally commenced their life history at the same epoch, but the smaller one, going through its changes more rapidly, is now found to be yellower than the other. Additional confirmation is afforded by the very great mass of the companions of Sirius and Procyon, notwithstanding the faintness of their light.

At the same time, up to at least the yellow stage, the star continually grows hotter as it condenses. A difficulty may here suggest itself in reconciling this order with a well-known physical fact. As a radiating body increases in temperature, its color changes from red through yellow to white, and the average wave length of its light continually diminishes. We see a familiar example of this in the case of iron, which, when heated, is first red in color and then goes through the changes we have mentioned. The ordinary incandescent electric light is yellow; the arc light, the most intense that we can produce by artificial means, is white. When the spectrum of a body thus increasing in temperature is watched, the limit is found to pass gradually from the

red toward the violet end. It would seem, therefore, that the hotter stars should be the white ones and the cooler the yellow or red ones.

There are, however, two circumstances to be considered in connection with the contracting star. In the first place, the light which we receive from a star does not emanate from its hottest interior, but from a region either upon or, in most cases, near its surface. It is, therefore, the temperature of this region which determines the color of the light. In the next place, part of the light is absorbed by passing through the cooler atmosphere surrounding the star. It is only the light which escapes through this atmosphere that we actually see.

In the case of the Sun all the light which it sends forth comes from an extreme outer surface, the photosphere. The most careful telescopic examination shows no depth to this surface. It sends light to us, as if it were an opaque body like a globe of iron. This surface would rapidly cool off were it not for convection currents bringing up heated matter from the interior. It might be supposed that such a current would result in the surface being kept at nearly as high a temperature as the interior; but, as a matter of fact, the opposite is the case. As the volume of gas rises, it expands from the diminished pressure and it is thus cooled in the very act of coming to the surface.

In the case of younger stars, there is probably no photosphere properly so called. The light which they emit comes from a considerable distance in the interior. Here the effect of gravity comes into play. The more the star condenses, the greater is gravity at its surface; hence the more rapidly does the density of the gas increase from the surface toward the interior. In the case of the Sun, the density of any gas which may immediately surround the photosphere must be doubled every mile or two of its depth until we reach the photosphere. But if the Sun were many times its present diameter, this increase would be less in a still larger proportion. Hence, when the volume is very great the increase of density is comparatively slow; there being no well-defined photosphere, the light reaches us from a much greater depth from the interior than it does at a later stage.

The gradual passing of a white star into one of the solar type is marked by alterations in its spectrum. These alterations are especially seen in the behavior of the lines of hydrogen, calcium, magnesium and iron. The lines of hydrogen change from broad to thin; those of calcium constantly become stronger.

Of the greatest interest is the question—at what stage does the temperature of the star reach its maximum and the body begin to cool? Has our Sun reached this stage? This is a question to which, owing to the complexity of the conditions, it is impossible to give a precise answer. It seems probable, however, that the highest temperature is reached in about the stage of our Sun.

The general fact that every star has a life history—that this history will ultimately come to an end—that it must have had a beginning in time—is indicated by so great a number of concurring facts that no one who has most profoundly studied the subject can have serious doubts upon it. Yet there are some unsolved mysteries connected with the case, which might justify a waiting for further evidence, coupled with a certain degree of skepticism. Of the questions connected with the case the most serious one is: How is the supply of energy radiated by the Sun and stars kept up? Only one answer is possible in the light of recent science. It is that already given in the last chapter—the continual contraction of volume. The radiant energy sent out is balanced by the continual loss of potential energy due to the contraction.

On this theory the age of the Sun can be at least approximately estimated. About twenty millions of years is the limit of time during which it could possibly have radiated anything like its present amount of energy. But this conclusion is directly at variance with that of geology. The age of the earth has been approximately estimated from a great variety of geological phenomena, the concurring result being that stratification and other geological processes must have been going on for hundreds—nay, thousands of millions of years. This result is in direct conflict with the only physical theory which can account for the solar heat.

The nebulæ offer a similar difficulty. Their extreme tenuity and their seemingly almost unmaterial structure appear inadequate to account for any such mutual gravitation of their parts as would result in the generating of the flood of energy which they are constantly radiating. What we see must, therefore, suggest at least the possibility that all shining heavenly bodies have connected with them some form of energy of which science can, as yet, render no account. This suspicion cannot, however, grow into a certainty until we have either seen the nebulæ contracting in volume or have made such estimates of their probable masses that we can compute the amount of contraction they must undergo to maintain the supply of energy.

In the impressive words of Sir William Huggins:

"We conclude filled with a sense of wonder at the greatness of the human intellect, which from the impact of waves of ether upon one sense-organ, can learn so much of the Universe outside our earth; but the wonder passes into awe before the unimaginable magnitude of Time, of Space and of Matter of this Universe, as if a Voice were heard saying to man: 'Thou art no Atlas for so great a weight.'"

MICROBES IN CHEESE-MAKING.

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CHEMISTS tell us that cheese is one of the most nutritious and, at the same time, one of the cheapest of foods. Its nutritive value is greater than meat, while its cost is much less. But this chemical aspect of the matter does not express the real value of the cheese as a food. Cheese is eaten, not because of its nutritive value as expressed by the amount of proteids, fats and carbohydrates that it contains, but always because of its *flavor*. Now, physiologists do not find that flavor has any food value. They teach over and over again that our foodstuffs are proteids, fats and carbohydrates, and that as food flavor plays absolutely no part. But, at the same time, they tell us that the body would be unable to live upon these foodstuffs were it not for the flavors. If one were compelled to eat pure food without flavors, like the pure white of an egg, it is doubtful whether one could, for a week at a time, consume a sufficiency of food to supply his bodily needs. Flavor is as necessary as nutriment. It gives a zest to the food, and thus enables us to consume it properly, and, secondly, it stimulates the glands to secrete, so that the foods may be satisfactorily digested and assimilated. The whole art of cooking, the great development of flavoring products, the high prices paid for special foods like lobsters and oysters—these and numerous other factors connected with food supply and production are based solely upon this demand for flavor. Flavor is a necessity, but it is not particularly important what the flavor may be. This is shown by the fact that different peoples have such different tastes in this respect. The garlic of the Italian and the red pepper of the Mexican serve the same purpose as the vanilla which we put in our ice-cream; and all play the part of giving a relish to the food and stimulating the digestive organs to proper activity.

The primary value of cheeses is, then, in the flavors they possess. One can hardly realize the added pleasure they give to the life of hundreds of thousands of poor people whose food must be of the coarsest character. A bit of well-flavored cheese adds relish to the humblest meal and gives the highest delight. We must recognize, then, that the chief value of the cheese lies exactly in these flavors which the chemist does not include in his analysis of cheese and which the physiologist refuses to call food or to regard as having any nutritive

value whatever. Incidentally, it is true that the cheese also furnishes a considerable amount of food material. Thus it nourishes as well as stimulates and delights; but, after all, we must recognize that its chief value is in its flavor rather than in its nutritive quality.

Hence it becomes a very significant question to inquire into the source of this flavor. We find, first, that the cheese as originally made possesses no flavor, or, at least, none of that peculiar flavor which we know as cheesy. Cheese is made from milk by causing the casein in the milk to be precipitated, *i. e.*, causing the milk to curdle, commonly by the addition of rennet, or, in so-called Dutch cheeses, by simply allowing the milk to sour. The precipitated casein is then separated from the liquids of the milk, and the curd, when subsequently pressed and molded, becomes the cheese. But the freshly-made cheese possesses no flavor, nor does the flavor develop to any degree until after it has passed through a process known as 'ripening.' The ripening of cheese may take several days or several months, or, in some cases, one or two years; but the flavor always arises during this process. Moreover, the various cheeses with their varieties of flavors are mostly made from the same kind of milk, but are subjected to different modes of ripening, and the distinctive quality in the endless types of cheeses is due in large measure to differences in the method of bringing about this ripening. Clearly enough the flavor is a product of cheese ripening, and if we wish to find the source of these most valuable flavors we must seek it in the ripening process.

This cheese ripening proves to be a two-fold process. The first change in the cheese is a chemical one, which results in altering the chemical nature of the cheese in such a way as to render it more easy of digestion. This change appears to be due in part to a certain ferment which is found in milk. This material belongs to the class of chemical ferments or enzymes and is a normal constituent of milk, although its presence was not mistrusted until recently pointed out by two American investigators. With the chemical changes produced by this enzyme we are not here particularly concerned. It is certainly not the cause of all the flavors which develop in the cheeses, and, therefore, this character of the ripened cheese must be chiefly attributed to another factor. There is no doubt that this other factor is a living one. The flavors can generally be traced directly to the growth upon and within the cheese of a variety of plants; and the ripening is carried on in a fashion designed, at the same time, to stimulate the growth of some species of plants and to check the growth of others.

Cheeses are of two kinds, hard and soft. As implied in the name, there is a difference in the consistency of the cheese. But this is not all; for on account of the methods of manufacturing, the ripening is produced by different classes of plants in the two classes of cheeses.

In the soft cheese, the plants contributing most to the ripening and to the formation of the flavor are what are commonly called molds, at least in some cheeses, while in the hard cheeses the molds play probably no part, and bacteria are the most active agents in producing the flavors developed during the ripening.

In making the soft cheeses—little known in this country—the general mode of procedure is as follows: The milk, sometimes whole milk, sometimes partly skimmed, is caused to curdle by the action of rennet. The curd is either cut to pieces by knives designed for the purpose, thus allowing the whey to drain off more readily, or it is simply ladled out of the vessel in which it curdled and placed at once into forms. As the whey is drawn off from the forms, through holes in the sides or through a false straw bottom, the curd soon assumes the shape of the forms. It is at first very soft, since it is subjected to no pressure whatever. At short intervals this soft mass is turned, so as to rest upon a new surface, and this turning is continued for two or three days. By this time the curd has become dry and consistent enough to handle, and it is then carried off to the cheese cellar for ripening. The details of this process differ considerably. In quite a number of cheeses particular methods are adopted to favor and hasten the growth of molds. Sometimes it is laid upon special straw mats or wrapped in straw, which, having been used over and over again in the dairy, has become thoroughly impregnated with mold spores. The cheese is then placed in a cool, damp atmosphere, which causes the spores to germinate and grow upon the cheese, already slightly acid, and in a condition favorable to the growth of molds. They grow rapidly over the whole surface of the cheese, and this step in the process is not ended until a good covering of molds has developed. Sometimes, indeed, special methods are adopted to insure their proper development. In making the Roquefort cheese specially prepared bread is allowed to mold, and after it becomes thoroughly impregnated with the mold it is finely grated to a powder and mixed with the curd as it is placed in the form for shaping. Fine holes are pierced in the cheese by a special machine to let in the air which is necessary for the luxuriant growth of the molds. Such treatment insures, of course, a very rapid growth of these plants, inside as well as outside. Most commonly, however, the cheese-maker depends upon his straw mats for the molds, and expects them to grow chiefly on the surface. The molds which develop in the cheese are not all of the same species. The common blue mold is most usual, but most cheeses are not properly ripened until several species of molds grow together within them.

The development of molds, however, is by no means the end of the ripening, but rather its beginning. Indeed, in some of the soft cheeses

their growth is entirely prevented by a thorough salting and washing of the surface. In such cheeses the mold may grow within the mass, but not on the surface. Whichever method is used, however, the cheese is presently removed to the so-called 'cheese cellar' for its proper ripening. These cellars may be cool, damp rooms, or caves, and the flavor of some kinds of cheeses is largely due to the nature of the caves in which the subsequent ripening is carried on. In these cellars there is a constant but not very high temperature, and the atmosphere is generally damp. Since the temperature and the moisture are kept as constant as possible during the whole year, the cheese ripening can continue slowly and indefinitely. To a considerable extent differences in the ripening of soft cheeses are due to the different temperatures of the cheese cellars, and this determines the kind of plant life that shall flourish in this soft, nutritious food.

After the removal to the ripening chambers, a new series of changes begins in the cheese, due to new kinds of plant life. But as yet neither the cheese-maker nor the bacteriologist, who has studied the matter most carefully, can tell us much of the nature of the actual changes which occur during this ripening. When the cheese is placed in the ripening chamber it is certain that the growth of the molds is largely stopped, and it is also certain that here begins a growth of a new class of plants which we call bacteria. This moldy cheese, rendered alkaline by the growth of the molds, furnishes a favorable medium for the growth of different species of bacteria. At high temperatures they would speedily decompose the mass, even to extreme putrefaction, but at the low temperatures of the cheese cellars a complete putrefaction does not occur. Bacteria growth takes place probably in all soft cheeses, and as a result the nature of the cheese is profoundly modified. Numerous new chemical products make their appearance, either as by-products of decomposition or as actual secretions from the growing bacteria and molds. These new products have strong tastes and odors which, as they slowly develop, gradually produce the characteristic flavor of the ripened cheese. If the ripening continue long enough the decomposition grows too advanced even for the strongest palate. But when the proper ripening has been acquired and the tastes and flavors are of the desired character, the cheese is sent to market, highly flavored by the joint action of the bacteria and molds. It is still soft and moist, and the ripening process continues, so that the cheese will not keep good for a very long time. But while it is in the proper condition it furnishes the educated palate with a flavoring product of great intensity, and most highly relished by the numerous lovers of soft cheeses.

While such is the general method of manufacture of the soft cheeses, it must be recognized that the details of the manufacture differ widely. Differences in the kind of milk used, whether whole milk, skim milk,

sheep's milk, goat's milk, etc., differences in the handling of the soft curd, differences in the amount of salting and drying, differences in the temperature and moisture of the 'cheese cellar,' all result in the growth of different kinds of molds and bacteria, producing variously flavored products. It is evident, too, that the character of the product will depend upon the abundance and varieties of the plants which furnish the flavor. Unless a dairy is supplied with the proper species of molds and bacteria, it is hopeless to expect the desired results. Here lies the work which the scientist must perform for the further development of the cheese industry.

The second type of cheeses, with which we are more familiar in this country, is the type of hard cheeses. These are not only of denser consistency, but they have commonly a less pronounced taste and odor and are not so suggestive of decomposition. They are, also, commonly made in much larger form, their denser nature making it possible for them to be made in very large sizes. They keep longer and are, therefore, much more generally exported into different countries.

The difference between the hard and soft cheeses, great as it is in the perfected article, is due to quite slight variations in the method of manufacture. The hard cheeses are made from curdled milk, curdled in just the same way as in the making of soft cheeses. But, after the curdling and the cutting up the curd to allow the whey to separate, the curd is broken up into small bits and placed in forms, where it is subjected to heavy pressure. Sometimes, immediately after the cutting of the curd, it is subjected to a moderate heat. For example, the Swiss cheeses are heated to about 110° Fahr. for a short time after cutting up the curd. This heating changes the nature of the curd somewhat and gives it a tougher and more elastic texture. In all the hard cheeses the curd is finally placed in wooden forms and then subjected to pressure, moderate at first, but soon increased until the pressure is quite high. This pressure converts the curd into a very dense, compact mass, and one in which microscopic plants cannot so readily grow.

But the hard cheeses require a ripening to develop the flavor as well as the soft cheeses, and the ripening is a longer and slower process. The pressed cheese is placed in rooms, or caves, or other locality where the temperature is not very variable or where it can, perhaps, be artificially controlled. Here it remains for weeks and frequently for months, during which time it slowly changes its chemical nature as a result of the action of the chemical or organic ferments, and simultaneously acquires the flavors which characterize the perfected product.

It is generally believed that the flavors here, as well as in the soft cheeses, are due to the growth of microscopic plants; but the subject has proved a very difficult one to investigate. Molds play little or no part in ripening the hard cheeses. Indeed, their growth is prevented by

salting, oiling and rubbing the surface. But bacteria appears to have, if not the chief share, certainly a large share in the production of the flavors. Experiment has shown that bacteria grow abundantly in the cheese during the ripening; that some species of bacteria can produce in milk flavors similar to those found in the ripened cheese; that treatment which prevents the growth of bacteria prevents also the development of the flavors in the cheese. Further, in the manufacture of the famous Holland cheese (Edam cheese), the cheese-makers have learned that by planting certain species of bacteria in the milk out of which the cheese is to be made, the ripening may be hastened and made more uniform. In Holland about one third of the cheese is made by thus inoculating the milk with 'slimy whey,' which is simply a mass of whey containing in great numbers certain species of bacteria. These facts indicate strongly that the bacteria are agents in this flavor production. But, at the same time, the subject has proved so difficult of investigation that our bacteriologists are as yet by no means satisfied with the results. Indeed, they differ very decidedly in their conclusions. Some believe that the ripening is chiefly due to the same class of bacteria which produce the souring of milk; others think it due to bacteria which produce an alkaline rather than acid reaction; some believe it to be a combination of the two, while others, again, decide that cheese ripening is a long process, involving the action of many species of bacteria and perhaps of molds as well. The difficulty lies in the fact that, since the ripening is a long process, many species of bacteria are found in the cheese at different times. This makes it almost impossible to determine what is the cause of the ripening and what is only incidental.

It will be readily understood that the problem of cheese ripening is one most eagerly studied by bacteriologists. The immense financial interests involved in the discovery of definite methods of handling the manufacture and the ripening of cheese would insure this, entirely independently of any scientific interest. A very large per cent. of cheeses are ruined by improper ripening, and the discovery of methods for preventing this loss would mean the saving of millions of dollars annually. Moreover, many favorite cheeses have hitherto been capable of manufacture only in certain localities, probably because these localities are filled with the peculiar species of micro-organisms needed for their ripening. If it were possible to cultivate the requisite organisms and use them for artificial inoculation, it might be possible to manufacture any type of cheese anywhere. Already it has been found that new cheese factories may sometimes be stocked with the proper micro-organisms by rubbing the shelves and vessels with fresh cheeses imported from localities where the desired variety is nominally made. It is evident that immense financial interests may be involved in the proper

scientific solution of the micro-organisms for cheese ripening, and the practical application of the facts to cheese making.

As the result of these facts, many bacteriologists are engaged in the study of the problems connected with cheese ripening. Many new discoveries have been made, and various practical suggestions in cheese making have resulted from these researches. But every bacteriologist has been studying a different problem. In Holland some valuable studies of the ripening of Edam cheese have been made, but naturally, the results differ decidedly from those obtained by Swiss bacteriologists in their study of the ripening of Swiss cheeses, inasmuch as the Holland cheese itself is such a different product from that made in Switzerland. The study of cheese ripening in our own country will probably show little agreement with the researches in Europe, since our cheeses differ so much in taste from most of the continental cheeses, although they are not so very unlike the English cheeses. In short, the problems to be solved are as numerous as the varieties of cheese, and each problem has shown itself to be so complex as, thus far, almost to baffle the most patient investigation. It is true that one or two bacteriologists have announced that they have discovered the species of bacteria and molds which produce the ripening of the particular type of cheese that they have been studying, and in some cases cultures of these bacteria have been placed on the market for use in cheese making. In one case, a scientist announces that he has made many thousands of pounds of cheese by means of his artificial cultures and has met with the highest success. But, in general, these cultures have been of problematical value, none of them having, as yet, resulted in the extension of the manufacture of special types of cheeses in localities where it had been hitherto impossible.

As stated before, this country is perhaps more interested in the successful issue of these investigations than any other. Hitherto, Swiss cheeses have been made in Switzerland, Holland cheeses in Holland and all other types of cheeses in their own rather limited localities. This includes hard cheeses as well as soft. If we desire any of these products we are obliged, in the main, to import them. Certain imitations have been produced in this country, it is true; but the imitations are more in shape than in quality. If it were possible, however, for our dairymen to learn a method of making, not inferior imitations of European cheeses, but products actually their equal in flavor and quality, it is certain that an immense market would be speedily opened to them. This condition is probably dependent upon the success of the scientist in solving the problem of regulating the growth of bacteria and molds in the ripening cheese. As fast as the bacteriologist succeeds in showing how the ripening process may be so controlled as to make it possible for our dairymen to produce cheeses similar in character and equal in

grade to those of the European market, we may look for the expansion of the industry.

What the future may develop cannot be foretold. The problem is a large one, but the fruits of successful solution are great. Students of dairy bacteriology recognize the possibilities and have in recent years turned their attention quite largely to this subject. From continued experiments and investigations we may confidently expect some practical results, and it is not at all improbable that in a few years at all events, we may see an almost complete revolution in the manufacture of cheeses, especially in such a large country as this, where the possibilities for the development of cheese manufacture are almost unlimited, and where the demand must be as varied as the population.

SUBMARINE NAVIGATION.

By Professor W. P. BRADLEY,
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IN a paper read before the Society of Naval Architects, Nov. 11, 1898, Lieut. Commander W. W. Kimball, who commanded the torpedo flotilla during the war with Spain, said: "If it be granted that the surface torpedo boat has a place in naval warfare, and that her primary duty is the attack by night upon ships attempting blockade or raiding operations, then most assuredly the submarine torpedo boat has a most important tactical place, since she, and she alone, is competent to deliver a torpedo attack by day upon ships attempting blockading, bombarding or raiding operations. She is the only kind of inexpensive craft that can move up to a battleship in daylight, in the face of her fire and in spite of her supporting destroyers, and force that ship to move off or receive a torpedo. That there is no physical difficulty in the problem, is amply proved by the accurate functioning of the boat now in this harbor (the 'Holland'), which has shown to scores of doubters that perfect control in both the vertical and horizontal planes has been accomplished, that the boat can be held at any depth to within a foot, and be made to take porpoise-like dives, exposing the conning tower for only six or eight seconds, and can be steered on any desired course."

Rear-Admiral Jouett testified before the Senate Committee on Naval Affairs: "If I commanded a squadron that was blockading a port, and the enemy had half a dozen of these Holland submarine boats, I would be compelled to abandon the blockade and put to sea, to avoid destruction of my ships from an invisible source from which I could not defend myself."

Lieut. A. P. Niblack, who commanded the torpedo boat 'Winslow' during the latter part of the war, wrote in 'Marine Engineering,' December, 1898: "The crowning virtue of a submarine boat is that it makes blockades almost impossible. Strategically in war, it has a place all to itself." He is authority also for the statement: "If Spain had had the 'Holland' at Santiago, the blockade of that port by the United States would have been impossible, within the radius of action of the boat."

Admiral Dewey testified before the House Committee on Naval Affairs, April 23, 1900: "I saw the operation of the boat ('Holland') down off Mount Vernon the other day. I said then, and I have said

it since, that if they (the Spanish) had had two of those things in Manila, I never could have held it with the squadron I had."

Rear-Admiral Philip Hichborn, Chief of the Bureau of Construction, writes in 'Engineering Magazine' for June, 1900: "Submarines can secure our coasts more perfectly than they can be secured in any other way at present practicable."

Mr. W. R. Eckert, consulting engineer of the Union Iron Works, of San Francisco, which built the 'Oregon' and the 'Olympia,' said, after the trial of the 'Holland' of September, 1899, in Peconic Bay, Long Island: "I have been on the trial trips of many of the new vessels built for the Government, and would say that I would feel safer in the Holland boat when under water than in the engine or fire rooms of any of the fast torpedo boats."

Rear-Admiral Endicott says: "The Holland submarine torpedo boat will revolutionize the world's naval warfare. It will make the navies of the world playthings in the grasp of the greatest naval engine in history."

However successful or safe submarine navigation may be to-day, the story of its development shows sufficiently that the risks to be taken have been very great, even though the actual loss of life incurred has been, on the whole, remarkably slight. To the venturesome spirits who have sought thus to master the ocean depths the risk involved has only added a new fascination.

The history of man's attempts to penetrate the depths of the ocean is not brief. The diving-suit, indeed, is modern, but the diving-bell appears to have been known in the time of Aristotle and diving itself is as old as man.

But essential mastery of the depths can never be attained by these means. The expert diver can remain below but two minutes or so, at the most. The tenant of a diving bell or suit is not, indeed, so limited in time, but, because absolutely dependent upon the flexible tube by means of which air is pumped down to him by companions at the surface, he is limited in space, and, by conditions of weather and sea, is limited also as to times. In no such sense is he independent as is the captain of an ocean greyhound or man-of-war, or even as the lone lobsterman at the helm of an undecked boat. To be master under water one must navigate under water, and any contrivance deserving the name of submarine boat must be able not only to sink beneath the surface, but also by its own power to move about under water for a reasonable time freely and independently. They who go down to the sea in suits and bells are not navigators.

The number of recorded attempts truly to navigate under water is surprisingly large. In a report of the United States Fortifications

Board made in 1885 to the Forty-ninth Congress may be found a selected list of about fifty submarine boats. This list extends over a period of three centuries. It includes no boats which have been projected or described merely, nor even those which have been patented merely, but only such as had been actually built and practically tried up to that date. In the invention of these boats and in experimenting with them have been engaged the citizens of England, France, Holland, Spain, the Scandinavian countries, Italy, Russia and the United States —nearly all of the civilized countries. England has probably accomplished as little in this direction as any nation. France has shown by far the greatest zeal as a nation, and, on the whole, has been the most prolific. But the greatest practical success has been attained undoubtedly in our own country.

It would be a thankless as well as a wearisome task merely to enumerate the vessels of this list, still more so to describe them all, however briefly. Most of them were of ephemeral interest only. But there are some which should be mentioned in any account of submarine navigation, however concise.

Thus, in 1624 a Hollander named Cornelius Van Drebbell constructed a boat which was tried with some success in the Thames at London. James I. is said on one occasion at least to have been a witness of the experiments. But navigation under water in that day was an uncanny thing. Drebbell was regarded first as a magician, then as a madman, and then as an agent of the devil. Meeting no encouragement he died, and his secret died with him. It is curious to notice that Drebbell claimed to have discovered a certain fluid which possessed the power of purifying air vitiated by respiration. He called it 'Quintessence of Air.' From the standpoint of present knowledge this singular name and Drebbell's claim for the liquid are very suggestive. Oxygen was not discovered, as we believe, until a century and a half after Drebbell's time. But oxygen is the life-giving component of air. Moreover, volumetrically oxygen is the 'quintessence'—the fifth part—of air. Is it possible that Drebbell had discovered some liquid which easily disengaged the then unknown oxygen gas and thus was able to restore to vitiated air that principle of which respiration deprives it? Undoubtedly not. It is much more likely that he possessed a solution capable of absorbing the carbonic acid gas which is produced by respiration, and that the name given it was entirely fanciful and without special significance. But even if Drebbell's claim was a piece of pure quackery, with no substantial basis at all, it is nevertheless not without interest, for it shows, as we might have anticipated, that the problem of ventilation, one of the most important with which the inventors of submarines have had to deal, was at least appreciated by Drebbell the pioneer.

In the latter half of the eighteenth century, an engineer named Day made one successful dive in the harbor of Plymouth, England, in a boat of his own designing. He went down a second time and did not return.

It may be said in general that the necessities and opportunities of war have always been the greatest, indeed, almost the only incentive to experiments under water. The War of Independence proved remarkably stimulating to submarine invention. In 1775 David Bushnell, of Connecticut, constructed a diving boat for use against English men-of-war. A minute description of this boat is contained in a letter written by him to Thomas Jefferson in 1787. It resembled externally two upper turtle shells joined together by their edges, whence its name 'Tortoise.' It carried a crew of one man, but this man was not David

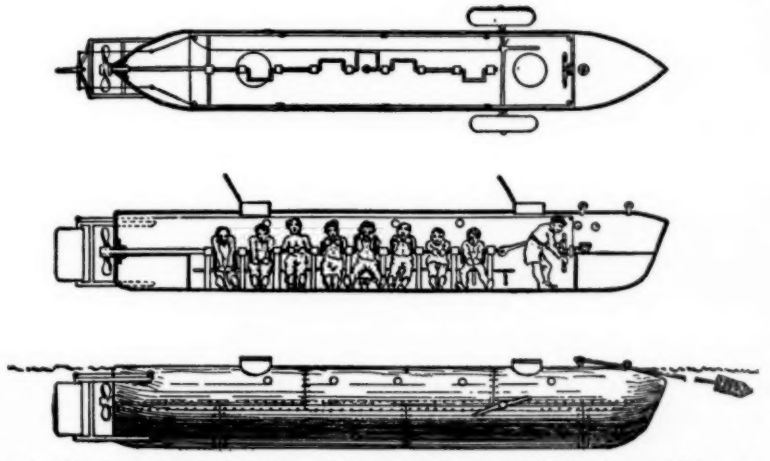


FIG. 1. THE CONFEDERATE SUBMARINE BOAT WHICH SANK THE U. S. STEAMSHIP 'HOUSATONIC IN CHARLESTON HARBOR DURING THE CIVIL WAR.

Bushnell, as it appears! During the harbor trials the boat was connected with the dock by means of a rope so that it might be recovered in case of accident. David Bushnell manipulated the safer end of this rope on the dock, while his brother, Ezra, and afterwards Sergeant Lee, did their best to learn the proper use of the mechanism within.

The following year, the first of the war, Sergeant Lee steered the 'Tortoise' beneath the hull of the British ship 'Eagle,' of 64 guns, lying off Governor's Island in New York harbor. He attempted to fix to her bottom a torpedo by means of a wood screw, but being rather unskillful still in maneuvering the 'Tortoise,' he lost the 'Eagle' altogether and was finally forced to the surface for air. Daybreak prevented further operations at that time. Two similar attempts were afterwards made on the Hudson, but they also failed and the 'Tortoise' was finally sunk by a shot.

In 1800 Robert Fulton, the father of steam navigation, built a very successful diving boat for Napoleon. It was called the 'Nautilus,' and possibly suggested the theme of that fascinating story, 'Twenty Thousand Leagues Under the Sea.' By its use, he actually succeeded in blowing up in the harbor of Brest an old hulk which had been provided for the purpose. But Napoleon's favor proved fickle, and Fulton's success led to nothing further at the time.

Early in the Civil War the Federal government entered into negotiations with a certain Frenchman to build and operate a submarine boat against Confederate vessels. It was desired in particular to blow up the Confederate 'Merrimac' in Norfolk harbor. Ten thousand dollars was to be paid for the boat when finished and $5,000 for each successful attack with her. The boat was constructed at the navy yard at Washington and paid for, whereupon the wily Frenchman decamped with his money, leaving the government to learn the secret of running the craft. This they never did. In fact, it seemed the general opinion that even the Frenchman would have experienced some difficulty in so doing.

Much more successful were the Confederates. The following account is condensed from Admiral Porter's 'Naval History of the Civil War': On the 17th of February, 1864, the fine new Federal vessel 'Housatonic,' 1,264 tons, lay outside the bar in Charleston harbor. At 8:45 P. M. Acting Master Crosby discovered something about 100 yards away which looked like a plank moving through the water directly toward his ship. All the officers of the squadron had been officially informed of the fact that the Confederates had constructed a number of diving boats, called for some reason 'Davids,' and that they were planning mischief against the Northern navy. Moreover, a bold, though unsuccessful, attempt of four months before to blow up the Federal 'Ironsides' was fresh in the minds of all. When, therefore, the officer of the deck aboard the 'Housatonic' saw this object approaching, he instantly ordered the anchor chain slipped, the engines backed and all hands called on deck. It was too late. In less than two minutes from the time of first discovery the infernal machine was alongside. A torpedo carried at the end of a pole thrust out from the bow of the stranger struck the 'Housatonic' just forward of the mainmast on the starboard side in direct line with the magazine. A terrific explosion took place, and the 'Housatonic' rose in the water as if lifted by an earthquake, heeled to port and sank at once, stern foremost. The crew, who most fortunately had reached the deck, took to the rigging and were soon rescued by boats from the 'Canandaigua,' which lay not far off. The 'David' was afterwards found fast in the hole made by her own torpedo. She had been sucked in by the rush of water which filled the sinking wreck. Her crew of nine were all dead

—killed doubtless not by drowning, though they must eventually have been drowned, nor as it would seem by suffocation, though in the end that would have followed; but probably by the concussion of their own torpedo.

The sublime heroism of these men is accentuated by the previous history of the 'David' to which they entrusted their lives. In her trial trip this boat sank for some unknown reason and her entire crew was drowned. Lieutenant Payne, her commander, escaped as by a miracle and succeeded in making his way to the surface. No sooner was the boat recovered from the bottom than he offered to try again. A new crew volunteered, and all went well for a time. But one night off Fort Sumter the boat capsized and four only escaped. The next essay was made under the lead of one of the men who had constructed the boat. This time she sank again and all hands were drowned. It was

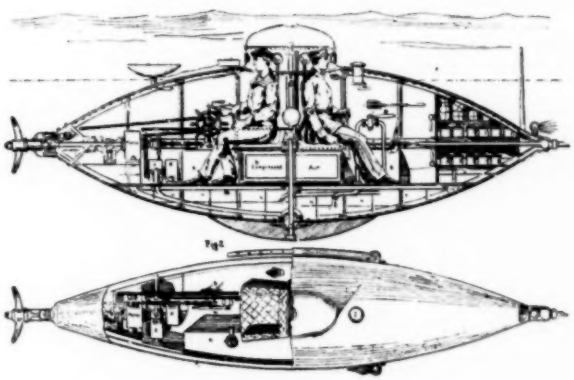


FIG. 2. GOUBET'S SUBMARINE TORPEDO BOAT.

such a boat, with such a history, in which that gallant crew of the 17th of February faced death and found it. North and South are united to-day as never before. We are permitted to treasure the memory of these brave men. They belonged to the same section as Hobson and displayed the same sublime heroism at Charleston as did he and his comrades at Santiago harbor.

The close of the Civil War marks an era in the history of submarine navigation. Previous to that time nearly all the boats were crudely designed and crudely built. Moreover, the nature and magnitude of the problems to be solved had not as yet been adequately understood. Whatever practical success has been achieved since is due to the fact that these problems have been thoughtfully and carefully studied, that those who have studied them have been in general better equipped therefor by education and training and have laid under requisition all the wealth of modern mechanical and physical science.

Of the many boats of this period, some of which have been quite

successful, one may easily recall the French 'Le Plongeur,' the 'Gustav Zédé,' the 'Morse,' the 'Narval,' the Nordenfeldt boats and those of Goubet and Baker. Here also belong, of course, the latest and most successful boats of all, the 'Holland' and Mr. Lake's 'Argonaut,' of which some account will follow.

Turning now from the history of submarine navigation to a consideration of certain practical problems connected with it, we are brought at the outset face to face with a fact of fundamental significance, namely, that even with the aid of very powerful electric illumination it is not possible to see clearly through ordinary sea water for more than a few feet. According to Mr. Lake of the 'Argonaut,' about fifteen feet is the limit of visibility in our Northern waters, and about twice that in Southern. Submarine navigation is like navigation in the densest sort of a fog. High speed under water is just as possible mechanically as upon the surface. But the fact just stated is a death blow to high speed. Unless there shall be discovered some hitherto unsuspected means of perceiving at a distance invisible objects, high speed will unquestionably be fraught with great peril.

For the same reason it will probably be found impracticable to attempt very long journeys under water. There will probably never be trans-sub-atlantic lines, much less submarine greyhounds.

In fact, practical inventors of submarine craft, at least of late years, have ceased to attempt to provide more than a *surface-going* boat which shall be able at any time or place to *dive* beneath the surface to the depth desired, to remain under water for considerable periods of time, either stationary or moving, with both safety and comfort to the crew, and then, the purpose of the dive having been accomplished, to return speedily and safely to the surface. Even these requirements constitute a pretty large contract, but that they have been met satisfactorily appears sufficiently, so far as the 'Holland' at least is concerned, from the quotations given at the beginning of the article, and from the further fact that our government, ultra-conservative in adopting new devices for use in warfare, has purchased the 'Holland,' which is now at Newport in charge of Lieutenant Caldwell, Admiral Dewey's aid at Manila, and that Congress has authorized the building of six more 'Holland' boats of an improved type. Two of these are now being built at the Union Iron Works, at San Francisco, the rest at Elizabethport, N. J.

Obviously, a prime essential for any sojourn under water is an ample supply of pure air. When possible to make use of it there is but one rational source of pure air, and that is the exhaustless supply at the surface. Provided she herself secures it, a submarine boat does not in the least surrender her independence by utilizing this supply. This the 'Argonaut' does at ordinary depths by means of a pair of vertical tubes, one for inflow, the other for discharge.

The method answers very well for the peaceful commercial work of the 'Argonaut.' In war, however, this would usually be impossible. The 'Holland' in action must be entirely concealed from the enemy for considerable periods of time. The normal air capacity of her hull is, therefore, supplemented by compressed air tanks capable of withstanding pressures upwards of a ton to the inch, and of holding 4,000 feet of free air compressed into the volume of thirty cubic feet. These tanks are recharged by her own engines when at the surface.

Ever since the days of Drebbell's 'Quintessence of Air' a great deal of thought has been given to the problem of purifying the air once

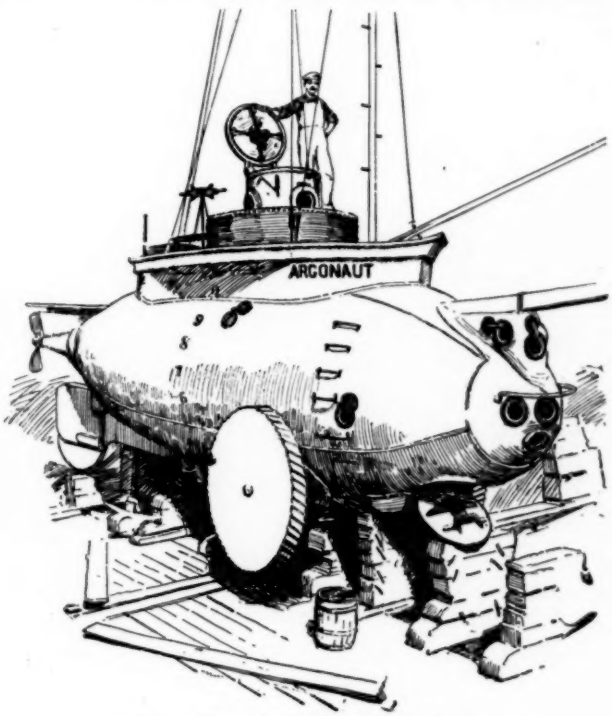


FIG 3. THE 'ARGONAUT' IN DRY DOCK.

vitiated by respiration and thus rendering it fit for use again. While it would seem to be a very simple task to restore from tanks or by chemical generation within the boat the oxygen which respiration consumes, and to absorb the water vapor and carbonic acid gas which respiration produces, those who have built the latest boats seem to have abandoned the attempt entirely. It is easy to imagine emergencies where fresh air could not well be obtained, and where such means of restoring air once breathed would be of prime value.

Objects under water are subject to pressure, which varies with the depth of submergence. At a depth of thirty-three feet this water pres-

sure is about fifteen pounds to the square inch, or more than a ton to the foot. Solid construction is naturally in order for a submarine boat. But power to resist pressure depends also upon shape. A circular section, because it involves the principle of the arch, is the strongest. With a given thickness of metal, therefore, a spherical boat could safely dive deeper than one of any other form. But the exterior of such a boat is ill-adapted to propulsion, and the interior for the arrangement of machinery.

Since the days of Captain Nemo and the fabulous 'Nautilus' the cigar shape has doubtless been associated with submarine navigation in

FIG 4. THE 'HOLLAND' IN DRY DOCK.

the minds of ninety-nine out of every hundred persons who have thought of the matter at all. And it is equally a matter of sober history that this form has been almost universally adopted. Some inventors in the earlier days, with the vision of high speed in mind, have trimmed down the lines to almost needle-like fineness, as in the 'Gustav Zédé.' Now that attempts at high speed have been abandoned, the elongated spheroidal or egg-shape is the favorite, as illustrated both by the 'Holland' and the 'Argonaut.'

But what of power for locomotion under water? Obviously steam power, at least as ordinarily produced elsewhere, will not do. Even supposing the necessary draft to be secured, how shall the smoke be

concealed, and how shall the crew endure the excessive temperature to which coal fires with little ventilation would subject them? Fortunately, the problem of power for propulsion is much simplified by the fact already mentioned, that for the most part, even a submarine boat lives and moves and has its being on the surface. When at the surface, steam power may be used as on any boat. Many of the earlier boats were thus equipped with boilers and steam engines. These served not only for surface propulsion, but were used also to store up

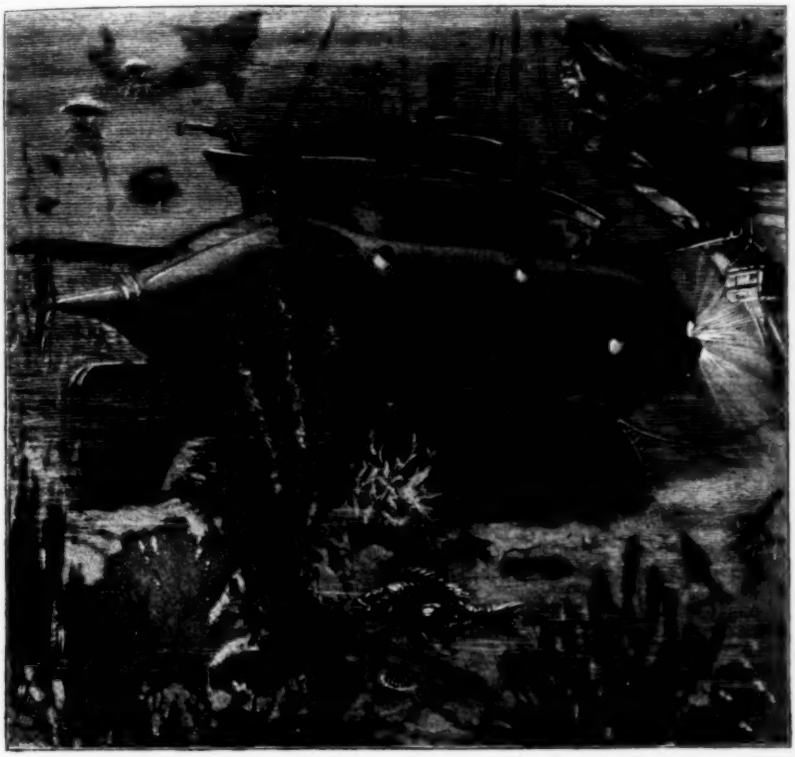


FIG. 5. SKETCH OF THE 'ARGONAUT' AS SHE MIGHT APPEAR AT THE BOTTOM OF THE SEA.

energy in the form of electricity or compressed air to be available as power when diving.

Nowadays gasoline and oil motors have been so perfected and they allow such economy of fuel space and withal such freedom from the dust, smoke and heat incident to a steam plant that they are coming into very general use, both afloat and ashore, where moderate amounts of power are required. Both the 'Holland' and the 'Argonaut' are equipped with gasoline engines. As these require for their operation much larger quantities of air than can be conveniently supplied from compressed air tanks, wherever concealment is necessary

and a supply of air from the surface is out of the question, recourse is still had as before to some form of storage power for propulsion. At present this is always electric.

The problem of diving demands attention next. For surface sailing a submarine boat, like any other, needs considerable buoyancy, so as to float with a considerable fraction of its bulk free above water. For diving, on the other hand, her buoyancy must be very small. These conditions are met by varying the amount of ballast carried. This is universally done by admitting water into, or expelling it from, suitable air-tight tanks distributed through the bottom of the boat. The filling of these tanks requires only the opening of a valve. To empty them

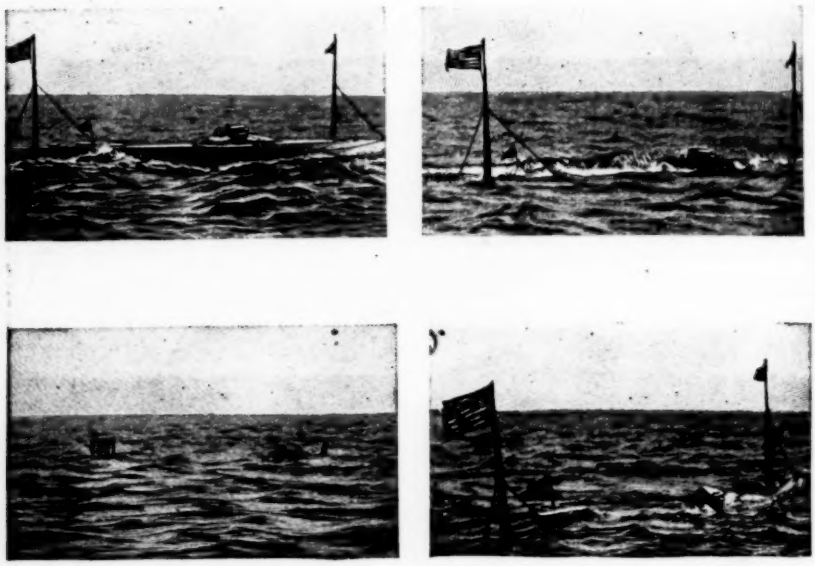


FIG. 6. PHOTOGRAPHS OF A TRIAL OF THE 'HOLLAND,' SHOWING HER IN CRUISING TRIM, IN DIVING TRIM, DIVING, AND RISING AFTER THE DIVE.

requires power. Formerly this was done by means of pumps. But pumping is slow work. A much more expeditious method of emptying the water tanks is to blow out the water by admitting compressed air from the reservoirs. The air so used is finally delivered into the living rooms for breathing, and the pressure in the reservoirs is restored again when at the surface. By thus varying the quantity of ballast a boat may be caused to sink, or, if already beneath the water, be caused to rise to the surface either slowly or rapidly as may be desired. It is easy to imagine circumstances, either accidental or otherwise, where a very sudden return to the surface might be imperative. To provide for this in emergencies the most practical boats are furnished with

a very heavy false keel of iron, which may almost instantly be detached by the throwing of a lever or the turning of a screw within the boat. The effect is precisely the same as that produced by throwing out a large quantity of ballast from the car of a balloon.

To sink a boat, take on sufficient ballast; to rise, discharge ballast, as in a balloon. But the ballast that will sink a boat beneath the surface at all will sink her to the bottom, and on the other hand if ballast be discharged until the rise begins, the rise will continue till the boat is again at the surface. To regulate the depth of submergence, therefore, something more is needed than mere adjustment of ballast. Practically there are but two ways of securing this regulation. One, repre-

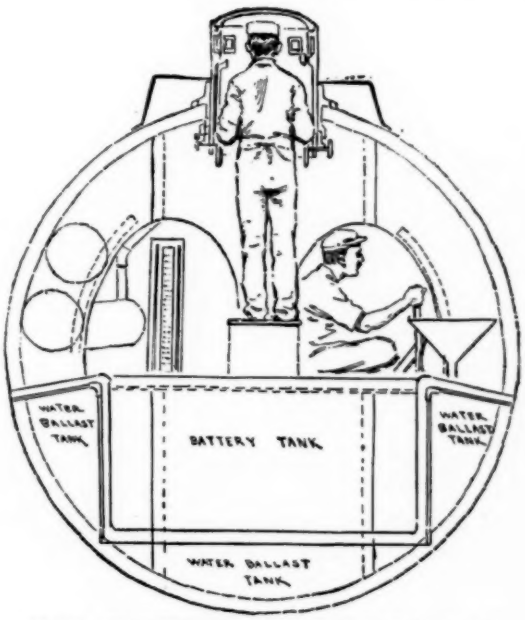


FIG. 7. CROSS SECTION OF THE 'HOLLAND' AMIDSHIPS.

sented in the Nordenfeldt boats and in some others, depends on the action of propellers arranged to act vertically instead of horizontally as do the ordinary. Although this method has the advantage of being applicable whether the boat is progressively in motion or not, it is now entirely abandoned. No sane person would advocate lateral propellers for moving a boat to right or left, and the disadvantages of vertical propellers for vertical motion are of the same order. The 'Holland' dives, rises or runs at a constant depth by the use of a rudder at the stern set at right angles to that for steering to right and left. By means of this rudder in the hands of a skilled steersman the 'Holland' can be held for a mile or over to within less than a foot of any depth desired.

As may be inferred from the quotations at the beginning of this article, the 'Holland' certainly embodies the highest attainments ever made in a submarine war vessel. In the words of Rear Admiral Hichborn, "The 'Holland' is an improvement upon anything that has ever been built in the history of the world." She is fifty-four feet long and is able with her forty-five H. P. gasoline engines to run considerably more than a thousand miles on the surface without recourse to any base of supplies, and, with her storage batteries and electric motors, thirty miles under water. Her offensive equipment is represented by an expulsion tube and three Whitehead torpedoes.

Her plan of operations when in the presence of a hostile vessel is to dive beneath the surface and steer by compass straight for the enemy. At intervals of a mile or so she rises till the top of her conning tower only protrudes, corrects her course and dives again. An emergence of eight to ten seconds only is required. Having arrived within a few hundred yards of the enemy the 'Holland' emerges for the last time, fires her torpedo, dives, turns back on her course and runs home.

During all this time she is perfectly protected by her invisibility. Even when rising she exposes so small a surface and that so low in the water that the chances are all against her being detected at all, especially as no one can tell when or where she will appear. Or if seen by the enemy there is no time to train guns upon her, and if there were, the chances are infinitesimal that so small an object could ever be hit. On the other hand, no defensive armor could save from absolute destruction a vessel once hit by the 'Holland's' torpedo.

After all is said which may be, of the terribly destructive power of the 'Holland,' or of any other submarine boat, it seems unquestionable that the greatest argument in favor of her adoption into a navy is not based thereupon, but rather upon the moral effect which would follow the knowledge that a nation possessed such a boat at all. "There is nothing more terrifying and demoralizing than to be attacked by an invisible foe; nothing more trying, bewildering and ineffective than striving to answer such an attack." If a captain of a battleship should see the turret of a submarine appear at the surface, straighten her course toward him, and then in ten seconds, before a shot could be fired, sink out of sight again, what would be his duty as a brave man, charged with responsibility for millions of property and hundreds of lives and with the performance of effective service for his country? To seek means of defense? There is no defense but flight, swift and immediate.

Hostile transports especially would not dare to approach a coast where the proximity of such a boat was suspected. High authorities insist that blockading also would be impossible if a harbor contained half a dozen of these terrible engines, which strike where no armor can

afford protection, which come one knows not whence nor when, and which are invulnerable because invisible. Any nation suitably equipped with such means of defense would be impregnable on the side of the sea.

Every submarine boat with a single exception, so far as the writer knows, has been designed solely or at least chiefly with reference to use in war. That exception is the 'Argonaut,' designed by Simon Lake and owned by the Lake Submarine Company.

The 'Argonaut' is intended for peaceful pursuits and is built and equipped accordingly. Her purpose is to save property, not to destroy it. Her work is to be quiet and prosaic, but none the less efficient and valuable. The success of her inventor and his company depends not upon the favor of governments and department officials, but upon the successful performance of forms of work which have a direct commercial value.

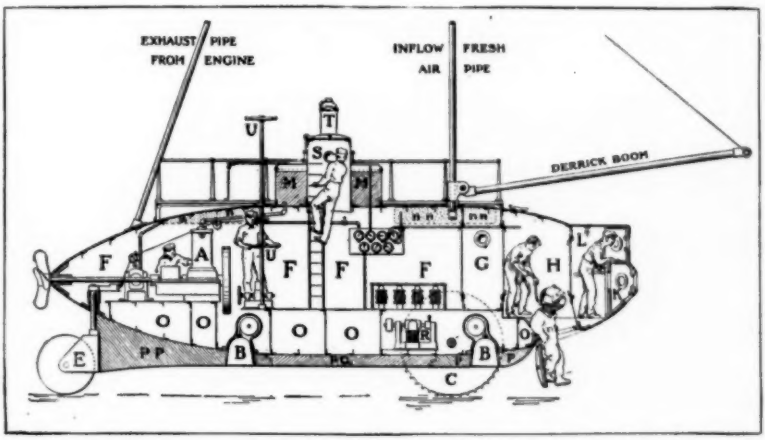


FIG. 8. LONGITUDINAL SECTION OF THE SUBMARINE BOAT 'ARGONAUT.'

She is built to travel on the bottom and is provided accordingly with wheels like a tricycle. Except in war, there is scarcely a single valuable object which can be served by navigation between the surface and the bottom. The treasures of the deep are on the bottom. On the bottom are the sponges, the pearls, the corals, the shell fish, the wrecks of treasure ships and coal ships and the gold-bearing sands. On the bottom are the foundations of submarine works, explosive harbor defenses and cables. To the bottom the 'Argonaut' goes, and on it she does her work.

Propelled at the surface by her gasoline engines, she looks much like any other power boat. The upper part of her hull is that of ordinary surface-going boats. Underneath she has the ovoidal form. Conspicuous on her deck are the two vertical pipes by means of which during submergence fresh air is drawn from the surface and the viti-

ated air within expelled. On the deck are also a derrick and a powerful sand pump for use in wrecking or in submarine construction, while a powerful electric lamp in her conical under-water bow illuminates the field of her operations. Most interesting is the sea door at the bottom forward, through which divers enter and leave the boat when on the ocean floor, the inrush of water into the diving compartment being prevented in the meantime by air pressure within, equal to and balancing the water pressure without. The 'Argonaut' has already traveled, it is said, hundreds of miles on the surface and scores on the ocean

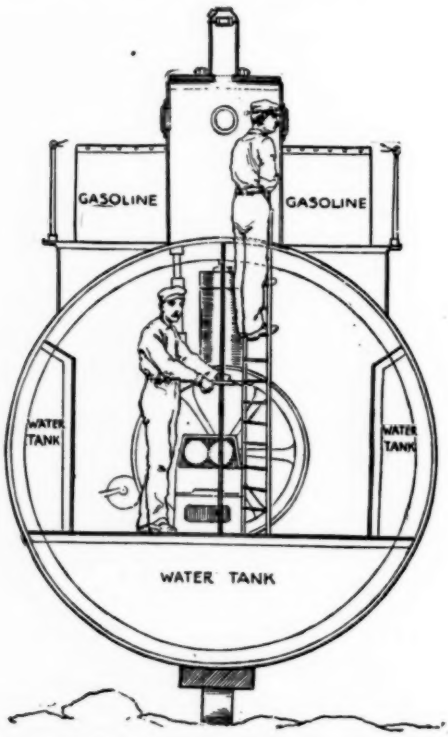


FIG. 9. CROSS SECTION OF THE 'ARGONAUT' AMIDSHIPS.

bottom. She can remain at the bottom as long as her gasoline and provisions hold out, with no other inconvenience to her crew than is occasioned by the somewhat restricted room within.

Mastery is the motto of mankind. Instinctively the race is ever obedient to that ringing commission of the Omnipotent: "Replenish the earth, and subdue it—and have dominion." Man longs to explore every unknown realm. He thirsts for knowledge, which is power, and by it he masters the mighty forces of nature and makes them his servants. It seems a little thing to have dominion over the habitable por-

tions of the earth—he must search the stretches of the desert, the realms of frost and eternal snow and the expanse of the sea. It is not enough to know the length and breadth of the earth—he must scale the heights of the mountains and penetrate the secrets of the great deep. Alexander weeping because, as he thought, there were no more worlds to conquer, is an ancient type of that same masterful spirit of which Kipling is the mighty modern prophet. But modern Alexanders find no place for tears.

According to competent judges, the submarine is to-day ready to serve mankind; the 'Holland' to make war less popular, the 'Argonaut' to make peace more valuable.

We should take genuine pride, should we not, in the fact that citizens of our own country are to-day foremost in the construction and use of these mighty engines?

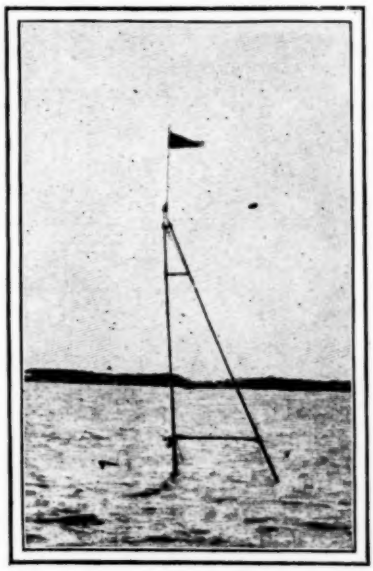


FIG. 10. THE 'ARGONAUT' SUBMERGED.

MUNICIPAL WATER-WORKS LABORATORIES.

By GEORGE C. WHIPPLE,

MT. PROSPECT LABORATORY, BROOKLYN, N. Y.

THE laboratory idea is fast taking hold of our municipalities. It is the natural result of modern science and American practicality. More and more our civilization is making use of the great forces of nature, and more and more is it becoming necessary that nature's laws should be understood: hence the need for the precise data of the expert and the long-continued observations of the specialist. This is emphatically true in the domain of sanitary science, where the advances in chemistry, microscopy and bacteriology have wrought revolutionary changes. The microscope is no longer a toy, it is a tool; the microscopic world is no longer a world apart, it is vitally connected with our own. The acceptance of the germ-theory of disease has placed new responsibilities upon health authorities and has at the same time indicated the measures necessary to be taken for the protection of the public health. With the knowledge that certain diseases are caused by living organisms and that these may be transmitted by drinking-water has come the need of careful supervision of public water supplies, which has resulted in the establishment of many laboratories devoted to water analysis.

The pioneer work of the Massachusetts State Board of Health and the Board of Health of New York City has been followed by the installation of laboratories in most of our large cities. In many cases these are operated in connection with departments of health, and the supervision exercised over the water supplies is of great benefit to the communities. An instance of this is furnished by the Health Department of Chicago. The water supply of Chicago is taken from Lake Michigan, and before the operation of the drainage canal the sewage of the entire city was discharged into the lake. The location of the water-works intakes was such that the water pumped to the city was subject to great changes in quality, varying from day to day according to the direction of wind and currents. For a long time it has been the practice of the department to issue daily bulletins as to the sanitary condition of the water in the city. Samples from the various sources of supply are received at the laboratory each morning, and upon the results of certain rapid methods of analysis the chemist bases his judgment as to the probable character of the water in the city mains during that day. The report is promptly given to the representatives of the press, and the consumers are thus warned of approaching danger.

The work of supplying water to a community is, however, an engineering problem, and for some years water-works' officials and engineers have felt the need of having in their own hands the means of determining the quality of the water. This has not been because they wished to assume duties pertaining to the health authorities or because they stood in fear of criticism, but because the management of the water supplies demands immediate information of a character not always appreciated by a physician and not always promptly obtainable from the laboratory of a health department. Accordingly, there has been developed in this country during the last decade an interesting group of water-works laboratories devoted to sanitary supervision and to experiments upon water purification.

The first of these laboratories was that of the Boston Water Works, established in 1889 by Mr. Desmond Fitzgerald, C. E., then Superintendent of the Western Division. At that time, and for several years previous, the water supplied to the city was in ill favor with the consumers because of its brown color and its vegetable taste. The primary object of the laboratory was the study of these objectionable conditions and the means for relieving them, but as the work proceeded it developed along broader lines. The laboratory, situated on the shore of Chestnut Hill Reservoir, consisted of a small frame building of two rooms, one used for general biological work and the other fitted up as a photographic dark room. The working force consisted of one biologist and three assistants, besides a number of attendants at the reservoirs, who devoted a portion of their time to the collection of samples and the observation of the temperature of the water. The following were the general outlines of the work:

The water supply of the city was derived from Lake Cochituate and from a series of storage reservoirs on the Sudbury River. The waters from these sources differed from each other and varied at different seasons of the year. Accordingly, a system of inspection and analysis was arranged in such a way that the superintendent knew at all times the exact condition of the water throughout the system. Samples of water were collected regularly from all streams tributary to the supply, from reservoirs at various places and at different depths, and from the aqueducts and distribution pipes. When these reached the laboratory they were examined microscopically and bacteriologically, the presence of any odor-producing organism was carefully noted and an immediate report was rendered when necessary. Careful observations of color were also made. When the work in Boston was started the methods of biological examination of water were in their infancy. The Sedgwick-Rafter method of ascertaining the number of microscopic organisms in water had just been devised and the methods of plate culture of bacteria were just becoming popular. The new methods were adopted in the Chestnut

Hill laboratory and constant use resulted in important improvements. The old method of obtaining the temperature of water beneath the surface by the use of a weighted thermometer gave way to the electrical 'thermophone,' and new methods for measuring the color of water were devised. An apparatus for photography was installed, and excellent photographs were made of all the important microscopic organisms in the water. A set of these photographs was on exhibition at the World's Fair in Chicago. In addition to the routine work, many lines of experimental work were undertaken. Studies were made upon the seasonal distribution of various organisms, the effect of temperature, light and air upon their growth, and upon the cause and nature of the odor imparted by organisms to drinking water. The effect of swamp-land upon water

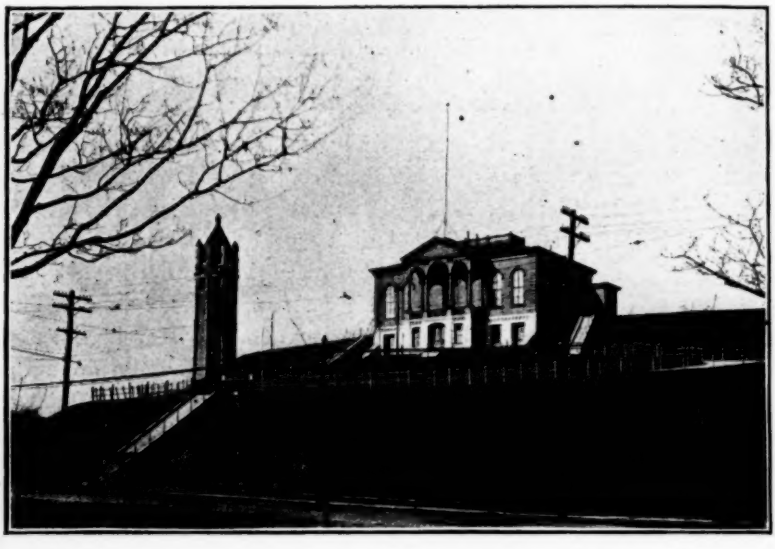


FIG. 1. MT. PROSPECT LABORATORY, BROOKLYN, N. Y.

supplies, the stagnation of deep lakes, the bleaching action of sunlight upon colored waters were likewise considered, while for several years the laboratory was operated in connection with an experimental filter plant.

After the Metropolitan Water Board assumed control of the water supply of Boston and its suburbs the laboratory was moved from Chestnut Hill Reservoir into the city, where it now occupies rooms at No. 3 Mt. Vernon street. In 1897 Dr. F. S. Hollis succeeded the writer as biologist, and he in turn has been succeeded by Mr. Horatio N. Parker. During recent years the conditions of the water supply have changed. New reservoirs of large capacity have been built, and the great Wachusett Reservoir is in process of construction. Swamps have been drained and filters have been installed where there was danger of polluted water

entering the supply. Thus new fields of work have been opened to the laboratory. The center of gravity of the system is now much farther from the city than formerly, and the logic of the situation points to the future establishment of a laboratory upon the watershed operated in connection with a department of sanitary inspection and equipped for chemical as well as biological work.

In 1893 the Public Water Board of the city of Lynn, Mass., fitted out a small room in the basement of the City Hall to serve as a laboratory for microscopical work. Weekly samples were collected from the supply ponds and examined by one of the lady assistants in the office. The results of the examinations were used by the superintendent in the operation of the works, and in several instances

FIG. 2. MT. PROSPECT CHEMICAL LABORATORY.

they proved the direct means of preventing the consumers from receiving water of an inferior quality. They also resulted in the undertaking of improvements in one of the reservoirs and tributary swamp areas that materially reduced the growths of troublesome algæ.

Bad tastes and odors in the water supply of Brooklyn, N. Y., led to the establishment of Mt. Prospect Laboratory by the Department of Water Supply in 1897. As this laboratory is typical of its class it deserves more than a passing notice. Situated upon the shore of Mt. Prospect Reservoir, near the entrance to Prospect Park, the laboratory has a fortunate location. In addition to being within convenient distance of the office of the department, the main distribution reservoirs of the city and the railway depot at which samples from the watershed are

received, its isolation and elevation make it comparatively free from noise and dust, while the building is well lighted by large windows, heated by hot water and provided with gas, electricity and telephone. The upper portion of the building contains three rooms, known as the general laboratory or preparation room, the biological laboratory and the chemical laboratory. In the basement are the physical laboratory, the furnace room and the general storeroom. The general laboratory is used for the shipment of samples, the washing of glassware, the sterilization of apparatus, the preparation of culture media and for such chemical processes as might charge the air with ammonia and the fumes of acids. The biological laboratory is devoted to the bacteriological and

FIG. 3. LABORATORY OF THE SEWER DEPARTMENT, WORCESTER, MASS.

microscopical examination of samples of water and to the study of the various organisms found. It also serves as the office of the director. The chemical laboratory is the largest of the three rooms. Its atmosphere is kept free from ammonia and acid fumes in order not to vitiate the results of the water analyses there carried on. Analyses of coal are also made in this room. A storage room opens from the chemical laboratory and there is also a small dark room. All three laboratories have marble tiled floors, and the tables and shelves are covered with white tiles throughout. The partitions between the rooms are largely of glass. The apparatus is of the most complete description, much of it having been designed for the particular work at hand. The physical laboratory

in the basement contains all the necessary apparatus for testing cement, analyzing sand, etc. The laboratory force consists of one biologist and director, one chemist, one assistant chemist and three assistants.

The routine work of the laboratory consists of the regular examination of samples of water from all parts of the watershed and distribution system, *i. e.*, from the driven wells, streams, ponds, aqueducts, reservoirs and service taps. The complicated and varied character of the water supply requires the examination of an unusually large number of samples, and it is safe to say that no water supply in this country is examined more thoroughly and minutely than that of Brooklyn. During the three years that the laboratory has been in operation over eight thousand samples have been analyzed.

The problems of the Brooklyn supply are very different from those met with in Boston. The supply is drawn, not from a few storage reservoirs of large size, but from a large number of small supply ponds, supplemented by an almost equal amount of water from deep and shallow driven wells. There are no extensive swamp areas, but the watershed is sandy and serves as a natural filtering medium. The entire supply, therefore, partakes largely of the character of ground water. The storage of ground water in an open reservoir has been almost always attended with troubles due to growths of microscopic organisms, and the Brooklyn supply has proved no exception to the rule. The mingling of surface water, seeded with plant life, and ground water, laden with plant food, has resulted in the enormous development of microscopic organisms in the distribution reservoirs. During the summer and autumn of 1896 the condition of the water in the city caused general complaint because of its bad odor. An examination, made by Dr. Albert R. Leeds, showed that the diatom asterionella was responsible for the trouble, and that the fishy odor was caused by an oil-like substance secreted by this microscopic plant. Since 1896 growths of asterionella and other odor-producing organisms have recurred regularly in the distribution reservoirs, but by the use of the new by-pass, through which water may be pumped around the reservoirs direct from the aqueduct to the distribution pipes, the water in the city has been kept comparatively free from them. The organisms appear and disappear according to laws that are now beginning to be understood, and while their growth in the Brooklyn reservoirs cannot be wholly prevented under present conditions, the laboratory is doing an important service by constantly noting their condition of growth and by forecasting their effect on the city supply for the guidance of the engineer in his manipulation of the reservoirs. The chief service of the laboratory, however, is in connection with the sanitary condition of the watershed, and upon this most of the bacteriological and chemical work is concentrated. The laboratory was installed and equipped under the direction of Mr. I. M.

De Varona, Engineer of Water Supply, with the writer in immediate charge.

The filtration of all surface water used for domestic supply is one of the probabilities of the future. For years many of the large cities of Europe have been supplied with filtered water, and in England alone more than ten million people are using water from which all danger from disease germs has been removed. In America filtration has gained ground but slowly, and in some of our cities the condition of the drinking-water is a disgrace to civilization. A German health officer once said to me: 'You Americans are a queer people; you filter sewage, but you drink water raw.' One reason for our tardiness in following the practice of the Old World is the fact that the conditions here are not in all respects the same as in Europe. The old methods of filtration cannot be successfully applied to many of our American waters, and water-works' engineers have felt that before expensive works were undertaken the problems should be carefully studied by direct experiment with respect to existing conditions. Thus, recent years have witnessed the operation of experimental filter plants unequalled in magnitude, in the scope of their work and in the accuracy of their methods of investigation.

The experiment station of the Massachusetts State Board of Health at Lawrence was started in 1897 and is still in operation. The results of the investigations of the principles involved in the purification of water and sewage by sand filtration have become classic in the annals of sanitary engineering, and the annual reports are still furnishing results of the highest scientific value. At the present time the work is in charge of Mr. H. W. Clark, Chemist of the Board. One practical result of these experiments was the construction of a sand filter of novel type for the purification of the water supply of the city of Lawrence, and the immediate reduction of the typhoid fever rate showed the success of the undertaking. The water of the Merrimac River, at Lawrence, though polluted, is comparatively clear, and it became evident that methods of filtration that were applicable to water of this character would not be necessarily successful where the water was highly colored and turbid. Experiments were, therefore, begun in other cities.

In Boston, where the water was of higher color than at Lawrence, and where microscopic organisms were sometimes numerous, a filtration station was in operation from 1892 to 1895. Six sand filters, each with an area of one-thousandth of an acre, and a large number of smaller filters, were used under varying conditions. The station was in charge of Mr. Wm. E. Foss, under the direction of Mr. Desmond Fitzgerald, C. E. The analytical work was done partly at the Massachusetts Institute of Technology and partly at the Biological Laboratory described above. It is much to be regretted that the results of these experiments were never published.

In 1893 Mr. Edmund B. Weston, C. E., of Providence, R. I., conducted for the water department of that city a series of experiments upon the purification of the water of the Pawtuxet River by means of mechanical filters. Though less extensive than the experiments above mentioned, they are of historic interest as giving the first adequate demonstration of the possibilities of that method of purification.

The system of mechanical filtration, or the 'American System,' as it is sometimes called, differs from natural sand filtration by the use of alum or some similar coagulating substance before sedimentation and filtration, by the higher rate of filtration employed and by the use of certain mechanical devices for cleaning the sand beds. The application of this process to the treatment of turbid water was next investigated. In 1895 the Louisville Water Company undertook a most extensive series of experiments to determine the relative efficiency of various types of mechanical filters in the purification of the water of the Ohio River. The work was placed in charge of Mr. Geo. W. Fuller, C. E., who was assisted by a large corps of trained assistants. For nearly a year the experiments were carried on without interruption: the filters were operated by the companies interested in them, and their efficiency was determined by Mr. Fuller on behalf of the water company, who had at hand a complete laboratory equipment and who used every means known to science in the analysis of the water before and after treatment. The most important result of these experiments was to prove beyond doubt the applicability of mechanical filtration to the purification of water rendered turbid by the presence of fine particles of clay.

The experiments in Louisville were followed in 1898-9 by a somewhat similar investigation at Cincinnati, O., also conducted by Mr. Fuller. As in Louisville, the water supply is taken from the Ohio River, but the character of the water at this point is not in all respects the same as that farther down stream. The problem in Cincinnati was to determine whether the English system of sand filtration or the American system, involving the use of a coagulant, was best suited to the purification of the water, and whether any preliminary treatment of the water before filtration was advisable. To solve this problem the Board of Trustees, Commissioners of Water Works, decided to appropriate for needed experiments a sum equivalent to about one year's interest on the probable cost of a plant for filtering the supply of the city. The equipment consisted of four steel tanks, each with a capacity of 100,000 gallons, fifteen experimental filters, arranged for operation under different conditions, and a large laboratory fully equipped for chemical and bacteriological work. After a period of continuous operation, covering about ten months, the evidence showed that either the American system or the English system operated with preliminary coagulation and sedimentation would satisfactorily purify the water, but that the American

system could be operated with less difficulty and with somewhat less expense.

In 1896 the city of Pittsburg, Pa., appointed a commission to consider the character of the water supply and the advisability of its purification by some means of filtration. The supply is taken from the Allegheny and Monongahela rivers, streams which are often turbid and which are subject to contamination by sewage. The conditions were such that direct experiment was necessary to determine the most suitable system of purification. Accordingly, an experimental station was located on the shore of the Allegheny River and placed in charge of Mr. Morris Knowles, under the direction of Mr. Allen Hazen, Consulting Engineer. Arrangements were made for the comparative study of sand filters and mechanical filters, and a laboratory was built and equipped for making all necessary analyses. The plant was in continuous operation for more than a year, and the results seemed to show that while satisfactory clarification of the water could be obtained by either system, the method of sand filtration could be depended upon to remove more completely the effect of pollution.

The report of a similar series of experiments made to determine the feasibility of purifying the water of the Potomac River at Washington, D. C., has been issued by the War Department. The work was carried on in a manner similar to that at Cincinnati and Pittsburg, the object of the studies being to find the best method adapted to the local conditions. Col. A. M. Miller, U. S. A., had charge of the investigations, and Mr. Robert Spurr Weston conducted the analytical work. Recently the Department of Public Works, of Philadelphia, Pa., has established a testing station near the Spring Garden Pumping Station for the purpose of studying the problems of filtration incident to the construction of filter beds for the water supply of the entire city, for which the sum of ten million dollars has been already appropriated. The work is in charge of Mr. Morris Knowles. Still more recently a testing station has been established by the Sewerage and Water Board of New Orleans, with Mr. Robert Spurr Weston as Resident Expert.

In July, 1899, the newly-constructed water filtration plant at Albany, N. Y., was put in operation, Mr. Allen Hazen having been Chief Engineer of construction and Mr. Geo. I. Bailey Superintendent of Water Works. In connection with this plant is a small laboratory in which are made daily bacteriological examinations of the water before and after filtration. Physical, chemical and microscopical examinations are also made at frequent intervals. The results obtained indicate the amount of purification that is taking place, and they already have shown that the filter is rendering efficient service in protecting the community from water-borne diseases.

The combined work of these various laboratories of supervision and

experiment has been of incalculable benefit to sanitary science, and the results have been not only of local and immediate value, but they have acquired a world-wide reputation and form a permanent contribution to scientific literature. If one doubts the practical worth of a laboratory in the management of a water-works system, no more convincing argument could be presented than the fact that a private water company in Wilkesbarre, Pa., has recently gone to the expense of establishing a laboratory for chemical, microscopical and bacteriological analyses of the water sold to the community, and this in spite of the fact that the water supply is taken from a watershed not seriously open to the danger of contamination. The work is in charge of Prof. Wm. H. Dean.

It is an interesting fact that in many instances the laboratories have been found to have a wider field of usefulness than that for which they were originally intended. For example, the laboratory in Cincinnati did not cease its existence when the filtration experiments were completed; it was continued as a laboratory for testing the materials of engineering construction. It is now in charge of Mr. J. W. Ellms, Chemist, under the direction of Mr. Gustav Bouscaren, Chief Engineer. The building has seven rooms and contains not only the apparatus necessary for water analysis and general chemical work, but a complete outfit for testing cement. The work now includes the chemical analysis of paints and oils, asphalts, rock, sand and cement, physical tests of cement, besides experimental investigations of the properties of cement mortars and asphalts.

At Pittsburg, also, the laboratory has been made permanent. The Department of Public Works has erected a two-story brick building, known as the Herron Hill Laboratory. The first floor and basement are used by the Bureau of Water Supply for water analysis, tests of supplies purchased and experimental work upon the filtration of water; the second floor is used by the Bureau of Engineering as a cement laboratory. In the water laboratory the floor and operating-shelves are covered with white tiles and the walls are painted with white enamel, so that the room may be washed from ceiling to floor. Steam from a neighboring boiler house is used for heating the water-baths and for distilling water. The incubators used for bacteriological work are placed in the basement, where the temperature can be kept more constant than on the floors above. The ammonia stills, sterilizers, autoclav and other apparatus are of the most modern type. A safe in the basement serves to protect the records in case of fire. One biologist, one chemist and one attendant are employed in the water laboratory, and a chemist is employed in the department of cement testing. Mr. Wm. R. Copeland is the biologist in charge.

In the Mt. Prospect Laboratory, of Brooklyn, the miscellaneous work is constantly increasing. The coal used at the various pumping stations

is purchased under specifications that require the analysis of a sample that must accompany every bid, and the determination of the heating power of a sample from every consignment. Lubricating oils, boiler compounds, samples of steel and other materials are analyzed and the laboratory is also equipped for the chemical and physical testing of cements.

Other departments of municipal work are taking up the laboratory idea. The Sewer Department of Worcester, Mass., has two laboratories. One is located at the disposal works and is devoted wholly to the supervision of the process of treatment of the sewage. The other occupies attractive rooms in the City Hall. Here a great variety of work is undertaken. During the year 1899 more than a hundred carloads of cement were used by the department, and over eight thousand samples were tested for tensile strength; many chemical analyses were also made. Bricks were frequently tested for absorption, and several samples of steel used in the construction of shovels and offered to the department by different dealers were analyzed. Coal, oil, lime and many other materials purchased by the department were analyzed. In addition to this, over seventy-five samples of butter and oleomargarine were examined for the Department of Milk and Butter Inspection, and a number of water analyses were made for the water department. A large amount of experimental work was carried on in connection with the problem of sewage disposal. Both laboratories are under the general direction of Mr. Harrison P. Eddy, Superintendent of Sewers.

It seems apparent, therefore, that the laboratory is destined to be an important factor in municipal engineering as well as in municipal sanitation, and it is not difficult to foresee a time when every city of importance will be provided with a laboratory equipped in accordance with its needs. In large cities, work of this kind is preferably specialized and distributed through different departments, in order that it may be under the control of those directly interested in the results, but in small cities, all the analytical work can be more economically accomplished in a single laboratory. In such a laboratory the work would cover a very broad field. Coal, cement, oil, brick, asphalt and various structural materials would be tested before purchase and during delivery; illuminating gas regularly examined; water, milk and various food products analyzed to determine their purity and healthfulness; bacteriological cultures made for diagnosis of diphtheria, typhoid fever, tuberculosis and kindred diseases; disinfection of buildings supervised, etc. All this would require the services of an engineer, a chemist and a bacteriologist, or of these three combined in one person. The expense of such an institution would be small in comparison with the saving that would result to the citizens in the purchase of supplies and in the protection of the public health.

FREEDOM AND 'FREE-WILL.'

By Professor GEORGE STUART FULLERTON,
UNIVERSITY OF PENNSYLVANIA.

LET us suppose two men before a jury on the accusation of homicide. Each admits that he has occasioned the death of a man, but each has his own account of how the thing came about. In the first instance, the accused was holding the gun that sped the fatal bullet; his finger was on the trigger and pressed it; the discharge followed; the victim fell. But it seems that the gun had been forced into his unwilling hands by one stronger than he; an iron finger lay above his own, and it was under its pressure that his finger became the proximate cause of a series of events which he cannot even now contemplate without horror. He was the unwilling instrument of a bloody deed, and does not account himself the responsible cause; he slew because he 'couldn't help it.'

The second man lays before his jurors a story in many respects different, but ending with the same words. He was alone when the shooting occurred. He was under no compulsion at the hands of another, but was shooting at a mark, and taking delight in dotting the target near the bull's-eye, when lo! across the field, above the hedge that bounds the horizon on that side, appears a tempting mark, the rubicund face of a rustic whose open mouth strikes his joyous mood at just that instant as an irresistible target, and one altogether too delightful to be passed by. "I had not the faintest intention, a moment before, of shooting any man," he explains; "but, really, it was too good a shot to miss, and I simply couldn't help it."

Let us suppose it possible for the same jury to hear these two explanations, one after the other. The action of a petit jury is said to be most uncertain, but there can be little doubt that even a jury would detect an important distinction between these two 'couldn't help's.' The world seems to be full of 'couldn't help's' of the two sorts; the man who stumbled on the stairs couldn't help rolling to the bottom; the man who was thrown from a window couldn't help descending to the street; the man who was seized by the police couldn't help failing to meet his engagement; the greedy boy couldn't help taking the larger muffin; the devoted mother couldn't help spoiling her only child; the emotional philanthropist couldn't help feeling in his pocket on hearing the plausible tale of the wily tramp.

Probably most jurymen would refuse to recognize 'couldn't help's'

of the second class as worthy of the name at all. Certainly, as jurymen, they have little concern with them. It is only with those of the first class that the law has to do, except in cases in which the sanity of the accused is in question. But suppose one of the jurymen happens to be a philosopher, and is accustomed to reflect upon matters which most men are in the habit of passing by without much thought. He may say to himself: "As a juryman I cannot think of listening to the absurd excuse for homicide offered by this second fellow. If I did I should have to admit that no man is a moral agent and that no crime should be punished. The smuggler, the burglar, the murderer, may be assumed to be influenced by motives of some sort. There is no case in which something may not be pointed to as that which occasioned the deed. Human life must be protected; society must be preserved; evildoers must be punished. If some men find the attractions of crime irresistible, so much the worse for them. And yet, as a philosopher, I find that I must accept the fact that, in a certain sense of the words, the guilty man couldn't help doing what he did. He was what he was; the target was attractive; the result followed. He was free from external compulsion, but he was not and could not be free from himself and his own impulses."

The man who reasons thus is called a determinist. Whether our determinist is wise to express things exactly as he does will appear in what follows. But the thought which he is at least trying to express is sufficiently clear. A determinist is a man who accepts in its widest sense the assumption of science that all the phenomena of nature are subject to law, and that nothing can happen without some adequate cause why it should happen thus and not otherwise. The fall of a raindrop, the unfolding of a flower, the twitching of an eyelid, the penning of a sentence—all these, he maintains, have their adequate causes, though the causes of such occurrences lie, in great part, beyond the line which divides our knowledge from our ignorance. Determinism is, of course, a faith; for it is as yet wholly impossible for science to demonstrate even that the fluttering of an aspen leaf in the summer breeze is wholly subject to law; and that every turn or twist upon its stem must be just what it is, and nothing else, in view of the whole system of forces in play at the moment. Much less is it possible to prove in detail that that complicated creature called a man draws out his chair, sits down to dinner, gives his neighbor the best cut of the beef, discusses the political situation, and resists the attractions of the decanter before him, strictly in accordance with law—that every motion of every muscle is the effect of antecedent causes which are incalculable only because of the limitations of our intelligence and our ignorance of existing facts. And yet the faith of science seems to those trained in the sciences a reasonable thing, for, as is pointed out, it is progressively jus-

tified by the gradual advance of human knowledge, and even in fields in which anything like exact knowledge is at present unattainable the little we do know hints unmistakably at the reign of law. There are few intelligent men who would care to maintain that the fall of a rain-drop or the flutter of an aspen leaf could not be completely accounted for by the enumeration of antecedent causes, were our knowledge sufficiently increased; but there are a considerable number who take issue with the determinist in his view of the subjection to law of all human actions. They maintain that there is a necessarily incalculable element present in such cases, and that all the antecedents taken together can only in part account for the result. As opposed to determinism they hold to the doctrine of indeterminism, or, as it has too often unhappily been called, the doctrine of 'free-will.'

I say as it has unhappily been called, because it is a thousand pities that an interesting scientific question, and a most difficult one, should be taken out of the clear atmosphere of passionless intellectual investigation, and, through a mere confusion, brought down among the fogs of popular passion and partisan strife. We have all heard much about fate and free-will, and no man with the spirit of a man in him thinks, without inward revolt, of the possibility that his destiny is shaped for him by some irresistible external power in the face of which he is impotent. No normal man welcomes the thought that he is not free, and the denial of free-will can scarcely fail to meet with his reprobation. We recognize freedom as the dearest of our possessions, the guarantee, indeed, of all our possessions. The denial of freedom we associate with wrong and oppression, the scourge and the dungeon, the tyranny of brute force, the despair of the captive, the sodden degradation of the slave. The very word freedom is enough to set us quivering with emotion; it is the open door to the thousand-fold activities which well up within us, and to which we give expression with joy.

But it must not be forgotten that the antithesis of freedom is compulsion, that hateful thing that does violence to our nature and crushes with iron hand these same activities. The freedom which poets have sung, and for which men have died, has no more to do with indeterminism than has the Dog, a celestial constellation, with the terrestrial animal that barks. St. Thomas and Spinoza, who differ in many things, have both pointed out that one must distinguish between the two latter, and the distinction is not broader than that which exists between the former. Determinism is not fatalism, and indeterminism is not the affirmation of freedom in any proper sense of that word, the sense in which men take it when it sets their pulses bounding and fills their breasts with high resolve. We have seen that even a determinist can distinguish between the two 'couldn't helps,' and recognize that they must be differently treated. We may now go so far as to insist that,

since they do differ so widely, they should be given different names, and we may call upon the determinist to avoid altogether, as other men do, the use of the term 'couldn't help' in the second sense. He may then say, without serious danger of being misunderstood, that the first prisoner at the bar couldn't help doing what he did, but that the second could have helped doing it if he had so elected. Without doing violence to the common use of speech, nay, strictly in accordance with common usage, he may declare that the one man was *not free*, but was under compulsion, while, on the other hand, the second man *was free*. He may very well do this without ceasing to be an out-and-out determinist.

Before going on with the topic which is the main interest of this paper, it is right that I should say just a word as to what determinism does not imply. It does not imply that all the causes which may be assumed to be the antecedents of human actions are material causes. A determinist may be a materialist, or he may be an idealist, or he may be a composite creature. As a matter of fact, there have been determinists of many different kinds, for the dispute touching the human will is thousands of years old; and the fact that the doctrine happens at the present time to be more closely associated in our minds with one of the 'isms' I have mentioned than with another, says little as to their natural relationship. Nor need the determinist necessarily be either an atheist, a theist, or an agnostic. He may, of course, be any one of these; but if he is, it will not be because of his determinism. As a determinist he affirms only the universal applicability of the principle of sufficient reason—the doctrine that for every occurrence, of whatever sort, there must be a cause or causes which can furnish an adequate explanation of the occurrence. I say so much to clear the ground. It is well to remember that materialists have been determinists, idealists have been determinists, atheists have been determinists, theologians have been determinists. The doctrine is not bound up with any of the differences that divide these, and it should not be prejudged from a mistaken notion that it necessarily favors the position taken by one of these classes rather than that taken by another. We may approach it with an open mind, and make an effort to judge it strictly on its own merits.

But to judge it on its own merits, the very first requisite is to purge the mind completely of the misconception that the 'freedom' of the will, or indeterminism, has anything whatever to do with *freedom* in the ordinary sense of the word—freedom from external compulsion. Here I sit at my desk; my hand lies on the paper before me; can I raise it from the paper or not, just as I please? To such a question, both determinist and indeterminist must give the same answer. Of course I can raise it or not, as I please. Both must admit that I am free in

this sense. The question that divides them lies a little farther back; the determinist must hold that, if I please to raise my hand, there is some cause within me, or in my environment, or both, that brings about the result; and if I please not to raise it, he must believe that there is some cause or complex of causes that produces just that result. He does not deny that I can do as I please. He merely maintains that my 'pleasing' is never uncaused. On the other hand, the advocate of the 'liberty of indifference' maintains that under precisely the same circumstances, internal and external, I may raise my hand or keep it at rest. He holds, in other words, that, if I move, that action is not to be wholly accounted for by anything whatever that has preceded, for under precisely the same circumstances it might not have occurred. It is, hence, causeless.

Now it would be a horrid thing to feel that one were not free to move or not to move. Freedom is a pearl of great price. But there is nothing especially attractive in the thought of causeless actions, in themselves considered. They strike one, at first glance, as at least something of an anomaly. It seems reasonable to suspect that the great attraction which the doctrine of indeterminism exercises upon many minds must be due to a confusion between it and something else. That this is indeed the case I can best illustrate by citing a passage from Professor James' delightful 'Talks to Teachers.'* It reads as follows:

"It is plain that such a question can be decided only by general analogies, and not by accurate observations. The free-willist believes the appearance to be a reality; the determinist believes that it is an illusion. I myself hold with the free-willists—not because I cannot conceive the fatalist theory clearly, or because I fail to understand its plausibility, but simply because, if free-will *were* true, it would be absurd to have the belief in it fatally forced on our acceptance. Considering the inner fitness of things, one would rather think that the very first act of a will endowed with freedom should be to sustain the belief in the freedom itself. I accordingly believe freely in my freedom; I do so with the best of scientific consciences, knowing that the predetermination of the amount of my effort of attention can never receive objective proof, and hoping that, whether you follow my example in this respect or not, it will at least make you see that such psychological and pyschophysical theories as I hold do not necessarily force a man to become a fatalist or a materialist."

I have taken this extract because it may stand as the very type of a 'free-will' argument, and as an ideal illustration of the persuasive influence of the ways of expressing things natural to a gifted writer. The school-teacher who has no prejudice against fatalism and materialism, to whom the idea of being endowed with freedom is not attractive, who

* Chapter XV., pp. 191-192.

is willing to have even good things fatally forced upon his acceptance, and who is not inspired by the thought of believing freely in his freedom, must be a poor creature indeed. But suppose Professor James had expressed his thought baldly; suppose he had said: "I myself hold to indeterminism, not because I fail to see the plausibility of the opposite doctrine, but because, if human actions *were* causeless, what more natural than that man should causelessly believe in their causeless origination? Accordingly, I causelessly believe in the causelessness of my actions, confident that no one knows enough about the matter to prove me in the wrong." Would the doctrine thus stated—and this only means the doctrine stripped of misleading associations—have proved particularly attractive?

It is not attractive even when superficially considered; it only seems arbitrary and unreasonable; a something to be taken rather as a play of fancy than as a serious argument. But looked into more narrowly, the doctrine is seen in its implications to be something very serious and terrible. So little has been said upon this topic in the vast literature of the dispute regarding the will, that I make no excuse for discussing it at some length. The issue has too often been clouded by the associations which hover about the words 'liberty,' 'freedom' and 'free-will,' and the true significance of indeterminism has not been clearly seen. I have said above that it is a pity to stir the emotions when one is trying to settle a question of fact; but as very much has been said upon the topic of the terrors of determinism that it is allowable, as an antidote to this poison, to point out the much more real terrors of 'free-will.'

Let us suppose that the 'libertarian' or 'free-willist'—the indeterminist—is right, and that human actions may be causeless. I am, then, endowed with 'freedom.' This is not freedom in the usual sense of the word, remember; and I have put it into quotation marks to indicate that fact. It means only that my actions cannot wholly be accounted for by anything that has preceded them, even by my own character and impulses, inherent or acquired. But, I ask myself, if I am endowed with 'freedom,' in what sense may this 'freedom' be called *mine*. Suppose that I have given a dollar to a blind beggar. Can *I*, if it is really an act of 'free-will,' be properly said to have given the money? Was it given because *I* was a man of tender heart, one prone to benevolent impulses, and naturally incited by the sight of suffering to make an effort to relieve it? Not at all; in just so far as the gift was the result of 'free-will,' these things could have had nothing to do with the matter. Another man, the veriest miser and skinflint, the most unfeeling brute upon the streets, might equally well have been the instrument of the benevolent deed. His impulses might all be selfish, and his past life a consistent history of sordid greed; I am a lover of my kind; but what has all this to do with acts of 'free-will'? If

they are 'free,' they must not be conditioned by antecedent circumstances of any sort, by the misery of the beggar, by the pity in the heart of the passer-by. They must be causeless, not determined. They must drop from a clear sky out of the void, for just in so far as they can be accounted for they are not 'free.'

Is it then *I* that am 'free'? Am *I* the cause of the good or evil deeds which—shall I say?—result from my 'freedom'? I do not cause them, for they are uncaused. And, since they are uncaused, and have no necessary congruity with my character or impulses, what guarantee have I that the course of my life will not exhibit the melancholy spectacle of the reign of mere caprice? For forty years I have lived quietly and in obedience to law. I am regarded as a decent citizen, and one who can be counted upon not to rob his neighbor, or wave the red flag of the anarchist. I have grown gradually to be a character of such and such a kind; I am fairly familiar with my impulses and aspirations; I hope to carry out plans extending over a good many years in the future. Is it this *I* with whom I have lived in the past, and whom I think I know, that will elect for me whether I shall carry out plans or break them, be consistent or inconsistent, love or hate, be virtuous or betake myself to crime? Alas! I am 'free,' and this *I* with whom I am familiar cannot condition the future. But I will make the most serious of resolves, bind myself with the holiest of promises! To what end? How can any resolve be a cause of causeless actions, or any promise clip the erratic wing of 'free-will'? In so far as I am 'free' the future is a wall of darkness. One cannot even say with the Moslem: 'What shall be, will be;' for there is no shall about it. It is wholly impossible for me to guess what I will 'freely' do, and it is impossible for me to make any provision against the consequences of 'free' acts of the most deplorable sort. A knowledge of my own character in the past brings with it neither hope nor consolation. My 'freedom' is just as 'free' as that of the man who was hanged last week. It is not conditioned by my character. If he could 'freely' commit murder, so can I. But I never dreamt of killing a man, and would not do it for the world! No; that is true; the *I* that I know rebels against the thought. Yet to admit that this *I* can prevent it is to become a determinist. If I am 'free' I cannot seek this city of refuge. Is 'freedom' a thing that can be inherited as a bodily or mental constitution? Can it be repressed by a course of education, or laid in chains by life-long habit? *In so far as any action is 'free,'* what I have been, what I am, what I have always done or striven to do, what I most earnestly wish or resolve to do at the present moment—these things can have no more to do with its future realization than if they had no existence. If, then, I really am 'free,' I must face the possibility that I may at any moment do anything that any man can 'freely' do. The possibility is a hideous one; and surely even the most

ardent 'free-willist' will, when he contemplates it frankly, excuse me for hoping that, if I am 'free,' I am at least not very 'free,' and that I may reasonably expect to find some degree of consistency in my life and actions. An excess of such 'freedom' is indistinguishable from the most abject slavery to lawless caprice.

And when I consider my relations to my fellow-men the outlook is no better. It is often said that the determinist may grant rewards or inflict punishments as a means of attaining certain desired ends, but that for him there can in all this be no question of justice or injustice. One man is by nature prone to evil as the sparks fly upward; another is born an embryo saint. One is ushered into this world, if not 'trailing clouds of glory,' yet with such clouds, in the shape of civilizing influences, hovering about the very cradle in which he is to lie; another opens his eyes upon a light which breaks feebly through the foul and darkened window-pane, and which is lurid with the reflections of degradation and vice. One becomes the favorite of fortune, and the other the unhappy subject of painful correction. Unless there be 'free-will,' where can we find even the shadow of justice in our treatment of these? We have all heard the argument at length, and I shall not enter into it further; nor shall I delay over the question of the true meaning of the terms *justice* and *injustice*, though this meaning is often taken for granted in a very heedless way. I shall merely inquire whether the assumption of 'freedom' contributes anything toward the solution of the problem of punishment.

Let us suppose that Tommy's mother is applying a slipper to some portion of his frame for having 'freely' raided the pantry. Does she punish him for having done the deed, or does she punish him to prevent its recurrence? In either case, she seems, if the deed was a 'free' one, to be acting in a wholly unreasonable way. Was the deed really done by Tommy— *i. e.*, was it the natural result of his knowledge of the contents of the pantry, his appetite for jam, and the presence of the key in the door? Not at all. The act was a 'free' one, and not conditioned by either Tommy's character or his environment. The child's grandfather might have 'freely' stolen jam under just the same circumstances. Thus, in a true sense of the words, the child did not do it. Who can cause what is causeless? Moreover, by no possibility could he have prevented it. Who can guard against the spontaneity of 'freedom'? No resolve, as we have seen, can condition the unconditioned. Then why beat the poor child for what he did not do and what he could not possibly have prevented? Surely this is wanton cruelty, and worthy of all reprobation!

Is the punishment intended to prevent a recurrence of the deed? How futile a measure! Does the silly woman actually believe that she can with a slipper make such changes in Tommy's mind or body as to

determine the occurrence or non-occurrence of acts which are, by hypothesis, independent of what is contained in Tommy and his environment? Does she forget that she is raining her blows upon a 'free' agent? As well beat the lad to prevent the lightning from striking the steeple in the next block.

The utter absurdity of punishing a 'free' agent, in so far as he *is* a 'free' agent, must be apparent to every unprejudiced mind. It is unjust and it is useless. And it seems clear that it is equally useless to make an effort to persuade him. To what end shall I marshal all sorts of good reasons for not doing this or that reprehensible action? To what end shall I pour forth my torrent of eloquence, painting in vivid colors the joys of virtue and the varied miseries which lurk upon the path of the evil-doer? Are my words supposed to have effect, or are they not? If not, it is not worth while to utter them. Evidently they cannot have effect in determining 'free' actions, for such actions cannot be effects of anything. It seems, then, that Tommy's mother and his aunts and all his spiritual pastors and masters have for years approached Tommy upon a strictly deterministic basis. They have thought it worth while to talk, and to talk a great deal. They have done what all pedagogues do—they have adjusted means to ends, and have looked for results, taking no account of 'freedom' at all. Of course, in so far as Tommy upon a strictly deterministic basis. They have thought it worth of the melancholy situation of the man who finds himself the father of half a dozen little 'free-will' monsters who cannot possibly be reached either by moral suasion or by the rod!

It is a melancholy world, this world of 'freedom.' In it no man can count upon himself and no man can persuade his neighbor. We are, it is true, powerless to lead one another into evil; but we are also powerless to influence one another for good. It is a lonely world, in which each man is cut off from the great whole and given a lawless little world all to himself. And it is an uncertain world, a world in which a knowledge of the past casts no ray into the darkness of the future. To-morrow I am to face nearly a hundred students in logic. It is a new class, and I know little about its members save that they are students. I have assumed that they will act as students usually act, and that I shall escape with my life. But if they are endowed with 'free-will,' what may I not expect? What does 'free-will' care for the terrors of the Dean's office, the long green table, and the Committee of Discipline? Is it interested in Logic? Or does it have a personal respect for me? The picture is a harrowing one, and I drop the curtain upon it.

Fortunately for us all, 'freedom' is the concern of the philosophers; *freedom* is what we have to do with in real life. The judge, the philanthropist, the moralist, the pedagogue, all assume that man may be a free agent without on that account being forced beyond the pale into

the outer darkness of utter irrationality. Men generally regard a man as free when he is in a position to be influenced by those considerations by which they think the normal man not under compulsion naturally is influenced. They do not think that he is robbed of his freedom in so far as he weighs motives, seeks information, is influenced by persuasion. What would become of our social system if men were not affected by influences of this sort? It would be the annihilation of all the forces which we have put in motion, and upon which we depend, for the amelioration of mankind.

There is scarce any tyranny so great as the tyranny of words. It is as reasonable to believe that strong drink will make a man strong, as that 'freedom' will make a man free, and yet how many believe it! So difficult is it to escape the snares of verbal confusion that I cannot be confident that some of my readers will not suppose that I have been arguing against human freedom. The forms of expression which have been chosen by some determinists are in part responsible for their error. The 'free-willists' are not wholly to blame. I feel, then, that I ought to close this brief paper with an unequivocal and concise statement of my position. It is this:

I believe most heartily in freedom. I am neither fatalist nor materialist. I hold man to be a free agent, and believe that there is such a thing as justice in man's treatment of man. I refuse to regard punishment as the infliction of pain upon one who did not do the thing for which he is punished, could not have prevented it, and cannot possibly be benefited by the punishment he receives. I view with horror the doctrine that the teacher's desk and the pulpit, the force of public opinion and the sanction of law, are of no avail. I am unwilling to assume without evidence that each man's breast is the seat of uncaused and inexplicable explosions, which no man can predict, against the consequences of which no man can make provision and which set at defiance all the forces which make for civilization.

CHINESE COMMERCE.*

By WILLIAM BARCLAY PARSONS.

THE foreign commerce of China is carried on through and at twenty-nine Treaty Ports. Previous to 1840 trade with foreigners was much hampered owing to its being subject to local regulations, all of which were annoying, many of them ridiculous, and some actually jeopardizing to both life and property. In 1842 Great Britain, availing herself of the successful outcome of what is known as the Opium War, stipulated that as one of the indemnities, China should declare the ports of Canton, Amoy, Fu-chow, Ning-po and Shanghai to be thrown entirely open to British trade and residence, and that commerce with British subjects should be conducted at these ports under a properly regulated tariff and free from special Chinese restrictions. Although Great Britain nominally secured for herself special considerations, she intended and actually accomplished the establishing of commerce between China and all other nations on a sound and liberal basis. The treaty of Nan-king was immediately followed by similar treaties with other powers, that with the United States being executed in 1844. Additional ports, decreed by treaties or other arrangements by the Chinese Government, have been added from year to year. At the end of the year 1899 the Maritime Customs reported twenty-nine of these ports, with several branch or sub-ports in addition. At nearly all of them there is a special reservation, called the foreign concession, where foreigners are allowed to reside and regulate their method of living in their own way. Although foreigners are permitted to dwell in the Chinese quarter if they so desire, the right to hold property in the concessions is usually denied to Chinese, and they are discriminated against in other ways.

Previous to 1860 the management of foreign commerce had been in the hands of Chinese officials, with the usually unsatisfactory result attending any official department handled by native overseers. In that year the business of the port of Shanghai was placed temporarily in the hands of English, American and French Commissioners, who were able to so improve the receipts by efficient and honest management that the Chinese Government, recognizing the desirability of continuing foreign supervision, organized the Imperial Maritime Customs and placed

*This article will form part of a book entitled 'An American Engineer in China' to be published shortly by Messrs. McClure, Phillips & Co.

the management of the whole foreign trade in the hands of a single Commissioner, called an Inspector-General, and appointed to this position Mr. Lay, succeeded in 1863 by Mr., afterward Sir, Robert Hart, who has continued in the control since then, and to whom is due the present very satisfactory condition of the management of this Bureau, to which has since been attached, in order to secure efficiency, a Marine Department, covering lighthouses and harbor regulations and the Chinese Imperial Post-office.

The ports open in 1899 were: Niu-chwang, Tien-tsin, Che-foo, Chung-king, I-chang, Sha-si, Yo-chow, Hankow, Kiu-kiang, Wu-hu, Nan-king, Chin-kiang, Shanghai, Soo-chow, Ning-po, Hang-chow, Wen-chow, San-tuao, Foo-chow, Amoy, Swa-tow, Wu-chow, Sam-shui, Canton, Kiung-chow, Pak-hoi, Lung-chow, Meng-tsz and Szmao. Of these Niu-chwang is located in the north, at the terminus of the Chinese Imperial Railway, and is the gateway through which the trade passes from China to Russian Manchuria. Two ports, Tien-tsin and Che-foo, are situated on the Gulf of Pe-chi-li, while the next eleven on the list, Chung-king to Soo-chow, are on the Yang-tze Kiang or its tributaries. Seven ports, Ning-po to Swa-tow, are on the East Coast. Wu-chow and Sam-Shui are on the West River. Canton is the great port of Southern China and the oldest seat of foreign trade in the country. Kiung-chow is on the Island of Hainan, and Pak-hoi, Lung-chow, Meng-tsz and Sz-mao are on the Franco-China frontier of Tong-king. The last three and Niu-chwang are the only places not situated on important waterways. Of the total foreign trade about three-quarters is transacted through Canton, Shanghai, Tien-tsin and Hankow, which are the great distributing points for the south, middle coast, north and interior.

The importance of Canton, Shanghai, Tien-tsin and Hankow is fixed by geographical conditions. Canton is at the head of the Canton River, which is really the estuary for the combined flow of the West, the North and the East Rivers, the three principal streams and consequent trade routes of Southern China. With its fine harbor and juxtaposition to Hongkong, it is of necessity, and must always continue to be, the gateway to the southern part of the Empire. In like manner, Shanghai, at the mouth of the Yang-tze, is the controlling point for the whole of the central zone; while Tien-tsin, the port of Peking, is the entrance to the north, the northwest and Mongolia. Hankow is at the head of steamship navigation on the Yang-tze, and at the junction of that stream and its principal tributary, the Han, and if the extreme western part of the country be omitted, which part is mountainous and very thinly populated, Hankow is approximately the geographical center of the Empire.

Native vessels trading between native ports report at custom-houses administered by native officials, where the records are hopelessly con-

fused, and which, as a source of income to the Chinese Government, need not be considered in this place.

The foreign commerce of China, both import and export, is growing steadily, having doubled since 1891, the figures for 1899 showing that foreign goods to the value of 264,748,456 Haikwan taels ($185,324,000) were imported, and native goods to the value of 195,784,332 Haikwan taels ($137,049,000) were exported, or a total commerce of 460,533,288 Haikwan taels.

Owing to the lack of internal communication, the distribution of Chinese commerce is singularly restricted. Of the imports more than one-half is confined to two classes of articles alone; thus cotton and cotton goods in 1899 accounted for 40.2 per cent., and opium, unfortunately, for 13½ per cent. In like manner the exports, silk and tea, stand out almost without competition with other articles; these two together also aggregating more than 50 per cent. of the total. Silk provided no less than 41.8 per cent. and tea 16.3 per cent. Kerosene oil, metals, rice, sugar and coal are other articles largely imported, and beans, hides and furs, mats and matting, and wool other exports.

Although the extent of the traffic entered at native custom-houses, or, at least, not passing through the Maritime Customs, cannot be ascertained, that it is considerable is well understood, as can be shown by the single item of the export of rice. The exportation of this article was in 1898 prohibited in order to prevent a possible shortage at home. The Maritime Customs, therefore, report no rice as having been shipped outward during that year. The Japanese Customs, however, report having received rice from China to the value of $2,000,000 United States gold. It had been smuggled out in native vessels through the native customs and the Government deprived of revenue. An amusing explanation of this is given, which so thoroughly illustrates Chinese methods as to be worth repeating. As rice forms the greatest single item in Chinese food, any falling off in supply threatens a famine, the one thing the Government most dreads. Such being the case in 1898, stringent orders were sent to the Customs Tao-tai in Shanghai to prohibit any export of the grain, the greatest source of supply for which being the Yang-tze Valley, Shanghai is the natural point of shipment. On account of the power attached to it, and the opportunities offered, the position of Shanghai Tao-tai is one specially sought after, and it is generally believed that the price paid for a three-year appointment, in the way of 'presents' to the Palace officials, is about 200,000 taels. Since the authorized emoluments are about 20,000 taels per annum, out of which expenses exceeding that amount must be paid, it is evident that great financial skill must be displayed by the official in order to make both ends meet. On receipt of the restraining order the Tao-tai, under the advice of the syndicate who were 'financing' him, held the order for

some days, during which time the energetic syndicate members bought all the rice in sight, put it in vessels and rushed it abroad to Japan, a country which buys the inferior grade of Chinese rice for home consumption and ships abroad its own superior article. As soon as the embargo was published, the value of rice afloat at once rose and the Tao-tai syndicate cleared a handsome profit. This illustrates Chinese fiscal methods, and warrants the statement that the actual foreign commerce of the country is greater than the figures indicate.

China levies on its foreign commerce a tariff for revenue only. The rate charged on nearly all articles is five per cent. on imports and exports alike, although there are some special rates and a number of articles on the free list. The actual average rate on imports and exports runs from three to four per cent. It is the general opinion of merchants in China that, should it become necessary to add to the Government's income, this rate could be increased without any serious detriment to foreign commerce. In Japan the Government has found it necessary, in order to derive more revenue, to seriously increase its customs tariff, so that the present charges range from thirty to fifty per cent. ad valorem.

Foreign articles destined for consumption at the treaty ports or places of importation pay no further taxes. When, however, they are sent into the interior they are obliged to pay internal transportation taxes, called 'Likin,' collected at various stations along the trade routes. These likin charges, although they form a perfectly legitimate method of taxation, are objected to by the Chinese quite as much as by foreign traders, on account of their uncertain amount, which, according to Chinese custom, is left largely to the official in charge, who collects as much as he can. The foreign nations, in order to obviate these difficulties, have arranged with the Chinese Government to permit foreign articles destined for the interior to pay a single tax of two and a half per cent. to the Imperial Maritime Customs and then to receive what is called a 'transit pass' entitling the goods to pass the interior likin stations without further charge. Unfortunately, these transit passes are not always respected by officials in the interior, unless they think that the shipper will appeal to a foreign government, and, therefore, the officials are apt to levy likin in accordance with their own needs, and of the total collected but a small part finds its way into the public treasury.

The native merchant has no such advantage as the foreigner in securing immunity from likin extortion, and has to resort to all sorts of subterfuges to escape the impositions of his own countrymen, one of the most frequent of such resorts being to keep his goods under the name of a foreign merchant if possible. Another device was told to me by a customs official on the West River, where the local farmers

raise tobacco which is consumed mostly in Northern Kwang-tung. If it were shipped direct it would be charged en route a large and uncertain likin tax, the uncertainty of the amount being the worst feature, as it may easily convert an apparently profitable transaction into a serious loss. To avoid this the tobacco is loaded on a sea-going junk and shipped to Hongkong. From there the junk brings it back and enters it at the point of original shipment as a foreign importation. For this the merchant secures a transit pass under which he ships it to its destination. He has paid the freight and import taxes of five per cent. each; the transit pass fee of two and a half per cent., and the shipping charges both ways to Hongkong, and the expense of rehandling. These items he can ascertain accurately beforehand, and, therefore, prefers paying them rather than run the likin gauntlet, which may be from ten per cent. to fifty per cent. or more.

The Chinaman is by very instinct a trader, is quick to see and seize an opportunity to turn a profit, and has, what few other Eastern Asiatics have, a high sense of commercial honor. Although the great mass of them is poor, yet there is a wealthy class, and there exists, even in the interior, a demand for much more than the mere necessaries of life.

Now, what have the United States done in the past in this great country, how do they stand there to-day, what can they do and what should they do in the future? These are the considerations that most concern us.

To answer the first two of these questions there are two sources of statistics which we can examine—the returns of the United States, and of the Imperial Chinese Maritime Customs. Unfortunately, both of these sources are rendered valueless for exact deductions because of Hongkong. This, as is well known, is a British colony, and one of the few places on the globe where actual free trade exists. Being a British colony, enjoying free trade and possessing a magnificent harbor, it has become a great depot, or warehouse, where goods, whose ultimate destination, either in China or anywhere else in the Far East, is not definitely fixed, are shipped in the first instance, and thence rebilled to the point of consumption.

In this act their nationality is lost, for the returns of the shipping nation classes them as exports to Hongkong, while China, of course, treats them as imports from that place. The import returns of the Imperial Maritime Customs show that nearly one-half of the foreign commerce entering China comes from Hongkong. Thence many writers fall into errors, either by taking the direct trade between China and any other country as limited to the reported figures, or by classing Hongkong under the head of Great Britain and Colonies. The conclusions reached in these ways are grievously wrong. Although foreign

goods are transshipped from Hongkong to Japan, the Philippine Islands, Siam and other parts of the Orient, yet at least three-quarters of all goods (of American probably a higher proportion) received there find their final market in China; so to determine approximately the exports from the United States, or from any other country to China, the only way is to add to the direct exports three-quarters of the shipments to Hongkong. And to determine the relative standing of the trade of several nations, we should deduct the Hongkong trade from China's total as shown by the returns of the Imperial Maritime Customs, and then compare the reported direct imports or exports. This last calculation will not yield the actual amount of trade by about one-half, but it will show with fair closeness the percentage of trade secured and the rate of increase. I have in this manner obtained the figures for the year 1893, the period just previous to the Japanese War; those of 1883 and 1873, respectively the tenth and the twentieth year preceding 1893; and those for 1898, the fifth year following, and also for 1899, the last complete year of normal trade conditions existing before the Boxer revolution. This table shows the import trade of China exclusive of Hongkong and the relative standing of the leading commercial powers, the actual trade of which is not as stated, for the table does not include shipments through Hongkong.

DIRECT EXPORTS TO CHINA.

	1873. Hk. Tls.	1883. Hk. Tls.	1893. Hk. Tls.	1898. Hk. Tls.	1899. Hk. Tls.
Total, except Hongkong	44,202,000	45,863,000	72,435,922	116,737,079	146,652,248
Great Britain	20,991,000	16,930,000	28,156,077	34,962,474	40,161,115
India	16,709,000	17,154,000	16,739,588	19,135,546	31,911,214
Japan	3,207,000	3,738,000	7,852,068	22,581,812	31,414,362
Continent of Europe	662,000	2,385,000	5,920,363	10,852,073	13,405,637
United States	244,000	2,708,000	5,443,569	17,161,312	22,288,745

In the above table all the Continental powers of Europe are grouped as one. From this it will be seen that the export trade of the United States, an insignificant amount in 1873, has now outstripped the combined exports from the whole Continent of Europe, and will be soon contesting for second place with India and Japan. Had it not been for sudden increased shipments in 1899 of certain special articles like coal on the part of these countries, which articles China can and should produce, the United States would have passed the Indian trade and be close on to that of Japan. In point of exports from China the United States trade in 1899 had reached a point surpassing that of any other country except Great Britain.

But along what lines have these increases been made? Do they represent only a greater outturning of raw material—the direct products of the soil—or of manufactured articles, carrying with them the results of American ingenuity and American labor, a form of export trade always the most desirable?

Taking the full list, there were, according to the United States Government classification, exports in 1893 under fifty-seven heads, but in 1898, according to the same classification, exports under seventy-six heads. The greater part of the increase in the five years (amounting to a total of $6,091,613) was due to manufactures of cotton, which increased $3,558,794; to raw cotton, which increased from nothing to $370,670; to manufactures of iron and steel, including machinery, $416,048; and to oils, chiefly kerosene, $1,055,797. The manufactures of cotton, which in 1898 amounted to $5,193,427, reached, during the next United States fiscal year (1899), $9,844,565. That is to say, the value of cotton cloths alone was, in the year 1899, almost as large as the value of the total American imports into China during the preceding year of all articles of whatsoever nature. This class of goods, the products of our New England and Southern mills, is the greatest single item of American commerce, and has already reached a point where, in certain grades, it dominates absolutely the Chinese market.

Taking drills, jeans and sheetings, the three great items of cotton goods consumed by the Chinese, and examining the trade of the three northern ports of Niu-chwang, Tien-tsin and Chefoo, American goods comprise of total receipts at the first: ninety-eight per cent., and at the second and third ninety-five per cent., the small remaining balance being divided between the English, Indian, Dutch, Japanese and other manufacturing nations. But quite as extraordinary as this there must be kept in mind the fact that of the total exports to all countries of American manufactures in cotton cloths, the Chinese market consumes just one-half.

Another article of American commerce that figured very small in the early returns, but now shows a great and increasing importance, is flour. It is shipped almost wholly to Hongkong, and thence forwarded to Canton, Amoy or other southern Chinese ports. In the fiscal year ending June 30, 1898, no less than $3,835,727 worth was exported from here, and during the corresponding period of 1900, a value of $4,502,-081. Wheat is not grown in southern China, and American flour has captured the demand, just as American cottons have done in the north. Next to Great Britain and Germany our best customer for American flour is China.

Such is the state of our Chinese trade to-day, and no one can find fault with its present condition and its recent development. But what of the future?

The success of the American commercial invasion depends absolutely on the maintenance of the existing status. China, in the liberality of the regulations affecting foreign commerce, is second to no other nation. In levying a tax, amounting to less than four per cent., she gives preferential duties to none, special privileges only as com-

pelled by the stress of force in Manchuria and Shan-tung, and extends a freedom of welcome to all. It is true that nations occupying Chinese territory make so far no invidious distinction between their own and other people; but it must be remembered that their tenure is only nominal, and while the title to these lands remains vested in China, it would be difficult, in the face of existing treaties, to impose discriminating rules. Let Russia, however, become legally, as she is virtually, possessed of Manchuria; let her Trans-Siberian railway be completed, and let her claim openly as her own, not only Manchuria, but also the metropolitan province of Chi-li, is it to be supposed for one moment that the present freedom and equality of trade that China offers will be maintained? If anyone believes this let him talk with those in China who direct the course of Muscovite affairs. These officials, when in a confidential mood, will explain that the Trans-Siberian railway is a Government enterprise, and that it is much more important for Russia to give low and special rates to Russian cotton and other manufactures which the Government is fostering at home than to look for a direct profit from the operation of the railway. And yet Manchuria and the northeastern part of China are to-day the best market for American goods. During the year 1899 no less than $6,297,300 worth of our cottons alone entered the port of Tien-tsin, and $4,216,700 worth entered the port of Niu-chwang in addition. The latter amount was for consumption in Manchuria, Chinese and Russian. It is interesting to note that the whole import trade (including exports through Hongkong) from Russia, Siberia and Russian Manchuria to the whole of the Chinese Empire amounted to less than the imports of two grades of American cotton goods at Niu-chwang alone. When, therefore, Russia seized Lower Manchuria, the country most interested next to China, whose territory was being despoiled, was not Japan, who was being robbed of her fruits of victory; was not Russia, who was adding another kingdom to her empire; was not Great Britain, the world's great trader, but it was, little as it was appreciated, the United States. The American interests in seeing commercial equality maintained, far and away transcend those of any other nation.

Foreign trade in China to-day is confined exclusively to the treaty ports located along the coast and up the Yang-tze River. When goods are shipped to China, they are resold by the foreign houses resident in these treaty ports to Chinese merchants, and by them in turn are retailed in the interior. So far, therefore, as the foreigner directly is concerned, his trade is confined simply to the outer edge of the country; to him the interior is a *terra incognita*. The success of a commercial invasion depends, not on these treaty ports, not on the purchase of goods along the outer edge of the country, but on the possibility of reaching directly that great mass of population which lies far away

from the sea, out of reach of existing means of transportation, and practically buried in the interior. If they cannot be got at, or if, when reached, they cannot and will not trade, then it is not worth while to consider any general forward movement.

In the course of my journey in the interior of China, I went through the province of Hu-peh, which the Yang-tze Kiang traverses; the province of Kwang-tung, lying along the China Sea, and, between these two, the province of Hu-nan, which practically had not been traversed before by white men. Here evidently was virgin soil, and its condition can, therefore, be taken as a criterion of what the Chinaman is when unaffected by foreign influences. Even here I found that, although the foreigner's foot might never before have trodden the streets of the cities, his goods were already exposed for sale in the shop-windows.

In thinking of the Chinese, especially those in the interior, we are wont to consider them as uncivilized; and so they are, if measured scrupulously by our peculiar standards. But, on the other hand, they might say with some justice that we are not civilized according to the standards that they have set for themselves, founded on an experience of four thousand years. With all its differences from ourselves, a nation that has had an organization for five thousand years; that has used printing for over eight centuries; that has produced the works of art that China has produced; that possesses a literature antedating that of Rome or Athens; whose people maintain shrines along the highways in which, following the precepts of the classics to respect the written page, they are wont to pick up and burn printed papers rather than have them trampled under foot; and which, to indicate a modern instance, was able to furnish me with a native letter of credit on local banks in unexplored Hu-nan, can hardly be denied the right to call itself civilized. In the interior—in those parts where no outside influence has ever reached—we found cities whose walls, by their size, their crenelated parapets, and their keeps and watch-towers, suggested mediæval Germany rather than Cathay. Many of the houses are of masonry, with decorated tile roofs, and elaborately carved details. The streets are paved with stone. The shops display in their windows articles of every form, of every make. The streams are crossed by arched bridges unsurpassed in their graceful outline and good proportions. The farmer lives in a group of farm buildings enclosed by a compound wall—the whole exceeding in picturesqueness any bit in Normandy or Derbyshire. The rich mandarin dresses himself in summer in brocaded silk, and in winter in sable furs. He is waited on by a retinue of well-trained servants, and will invite the stranger to a dinner at night composed of ten or fifteen courses, entertaining him with a courtesy and intricacy of etiquette that Mayfair itself cannot excel. Such are actual

conditions in parts of China uninfluenced by foreign presence, and so far the civilization of the interior is a real thing. That the Chinaman allows his handsome buildings to fall into disrepair; that his narrow city streets reek with foul odors; that the pig has equal rights with the owner of the pretty farm-house; and that the epicure takes delight at his dinner in sharks' fins instead of terrapin—these are merely differences in details; and if they are faults, as we consider them to be, they will naturally be corrected as soon as the Chinaman, with his quick wit, perceives his errors, when the opportunity to study Occidental standards comes to him.

Chang-sha, the capital of Hu-nan, is one of the most interesting cities in the whole Empire, as marking the very highest development of Chinese exclusiveness and dividing with Lhassa in Tibet the boast of shutting its gates tightly in the face of foreign contamination. In a previous chapter an account was given of how the present conservative governor had closed the schools organized by his more liberal predecessor, and had tried to root up the budding movement toward reform and progress. But he made one interesting and highly suggestive omission in allowing the electric-light plant to continue. When, at the end of our first day at Chang-sha, as I stood on my boat watching the city wall, the picturesque roofs, the junks on the shore and the surging crowd slowly lose their distinctness in the twilight, and then saw them suddenly brought into view again by the glare of the bright electric arcs as the current was turned on to light the narrow streets, I smiled as I realized the utter impossibility of stopping the onward march of nineteenth century progress, and that the Chinese themselves, even at the very heart-center of anti-foreignism, are ready to turn from the old to the new.

In the shop-windows at Chang-sha there are displayed for sale articles with American, English, French, German, Japanese and other brands. One shop, I noticed, displayed a good assortment of American canned fruits and vegetables. This is the condition of affairs, not in Shanghai or Amoy, open ports, but in the most exclusively Chinese section in the whole Empire. That the Chinaman will buy, that he will adopt foreign ways, there is no question; and he is just as ready to make the greater changes in his life that must result from the introduction of railways as to buy a few more pieces of cotton or a few more tons of steel.

But in order to buy more the Chinaman must be able to sell more; for no matter what his inclination may be, unless he has something to give in return, he cannot trade. The exports from China have been expanding gradually, and in step with the imports. In 1888 they were 92,401,067 taels; had increased to 116,632,311 taels in 1893, and had further advanced to 195,784,332 taels in 1899. The two great items

of Chinese export, as was shown above, are silk and tea. The output of silk is increasing steadily, especially in the manufactured form. The amount of tea exported, however, is not on the increase, being about the same that it was ten years ago, the tea trade having been adversely affected by the competition of Japan, Ceylon and India, where more favorable transportation facilities have given advantages. Both tea and silk, however, are staple articles, with no chance of substitutes being found, and the world's demand for both is steadily increasing. The possibility of enlarging the output of silk is great, for there are in Northern Kwang-tung alone large areas of land capable of producing mulberry, that are lying idle at present because there are no transportation facilities.

The idea we have of the interior of China as overpeopled, and with every square foot of land under cultivation, is entirely without foundation, except possibly in certain portions of the great loess plain in the north. There is a great amount of land, capable of producing crops of various kinds and of supporting a population, that to-day lies fallow and untilled. Given the means of sending their produce to the sea and so to the foreigner, the people of the interior will see to it that the produce is ready.

Then there are vast mineral resources that are practically untouched. China, with coal-fields exceeding in quantity those of Europe, imported last year no less than 859,370 tons of coal, valued at $4,477,670 gold, nearly the whole of which came from Japan. With railways to bring the output of the mines to market, there will not only be no importing, thus permitting at least that amount to be expended for other foreign goods, but there should be a large export of coal to Hongkong for foreign shipping, and to other Eastern countries for local consumption. In addition to the coal, there are beds of copper, iron, lead and silver that, to-day untouched, are only awaiting the screech of the locomotive whistle.

In short, the resources, both agricultural and mineral, are at hand to permit a foreign commerce to be carried on—to pay the cost of building of railways and to provide sustenance for a commercial invasion.

But as yet China has made no effort to develop her latent powers. As was shown, the bulk of her exports are confined to two articles, due to her people not utilizing their natural advantages in diversity of soil and climate. Each locality produces that single article which gives the best local result, without considering broad market conditions. Thus in the south it is mostly silk and rice; in the central zone, rice and tea, and in the north, millet and wheat. Every bit of valley land is cultivated, but the hills are let go waste. There are great areas of grazing land where some day the Chinese will let herds roam, producing beef and hides, which they will turn to commercial profit; while on other

hillsides, as I saw being done in places, they will set out forests, and arbor culture will be well suited to their patient ways. As yet they have worked their lands only with a view to home consumption; there are many ways in which they can devote them and their energies to furnish export articles for the imports they will buy.

The position of the United States in China is peculiarly advantageous, because, in the first place, China regards our country as friendly in the desire to protect rather than despoil her territory, and because, in the second place, other nations have been willing to see ours come forward when they would have objected most strenuously to the same advancement on the part of one of their own number. The men who guide our national affairs and foreign commerce should always see to it that China's confidence is not abused. But as for the friendliness of other nations toward us in relation to China, so soon as the pressure of American trade begins to be felt by them, efforts will be made to thwart it if possible; and it must be remembered that to-day all the machinery of commerce, in the way of banks, transportation companies, cable lines, and other forms, is in their hands. When the meeting of the American and European invasions takes place, unless we have an organization, a base and rallying point, a tangible something besides mere labels on boxes or bales as representing American force, the struggle will be a hard one, for the native is apt to judge his associates by the outward visible signs, and with a natural tendency to deal with the strongest. In this respect commerce in the Far East stands, and will stand for a long time, on a different footing from that of commerce in Europe.

In order to be thoroughly successful, to expand our trade far beyond its present boundaries, we should make a careful and intelligent study of the Chinaman in his tastes and habits. If we wish to sell him goods, we must make them of a form and kind that will please him and not necessarily ourselves. This is a fact too frequently overlooked by both the English and ourselves, but one of which the Germans, who may be our real competitors in the end, take advantage. For example, at the present moment, if a careful study were made of Chinese designs, the market for American printed goods could be largely broadened. It is not for our people to say that our designs are prettier; the Chinaman prefers his own, and he will not buy any other. The United States Minister to China, talking upon this subject, gave me a striking instance of foolish American obstinacy. The representative of a large concern manufacturing a staple article in hardware, let us say screws, had been working hard to secure an order for his screws, which he knew were better than the German article then supplying the demand. At last he obtained a trial order, amounting to $5,000, which he cabled out; but it was given on the condition that the screws be wrapped in

a peculiar manner, say in blue paper, according to the form in which the native merchant had been accustomed to buy them. Was the order filled? Not at all. The company cabled back that their goods were always wrapped in brown paper and that no change could be made. The order then went to Germany. To the American concern an order for $5,000 was of small moment, perhaps; but they overlooked entirely the fact that this was the thin edge of the wedge, opening a trade that could be developed into tremendous proportions. This instance is not isolated, for, unfortunately, the reports of all our consuls are filled with parallel ones.

A study must also be made of the grade and quality of the article shipped. It is no use to send to China, to be sold in the interior, tools, for instance, of the same high finish and quality that our mechanics exact in their own. A Chinaman's tools are hand-made, of rough finish and low cost. In the interior cities one sees a tool-maker take a piece of steel, draw all the temper, hammer it approximately to the shape of the knife or axe, chisel or razor, or whatever other article he may be about to make; then, with a sort of drawing-knife pare it down to the exact shape required, retemper it, grind it to an edge and fix it in a rough wooden handle. This work is done by a man at a wage of about ten cents a day, and this is the competition that our manufacturer must meet. In spite of the difference in cost of labor he can do so, because his tools are machine-made and are better; but he must waste no money on unnecessary finish.

As an example, the case of lamps is directly to the point. The Chinaman fairly revels in illumination; he hates the dark, and everywhere, even in the smallest country towns wholly removed from foreign influence, it is possible to buy Standard oil or its competitors in the Chinese market, the Russian and Sumatra brands. The importation of illuminating oils is increasing tremendously. In 1892 it was 17,370,600 gallons, and in 1898 it was 44,324,344 gallons. But what of the lamps in which this oil is burned? In 1892 the United States sent to China lamps to the value of $10,813, and in 1898 to the value of $4,690. That is to say, lamps are one of the few articles which show a decrease. While the consumption of oil had increased more than two and one-half times, the importation of American lamps had decreased in almost the same ratio. This was not due to the manufacture of lamps in China, but to the German and Japanese manufacturers making a study of the trade and turning out a special article. These lamps—and I saw them for sale everywhere, even in unexplored Hu-nan—have a metal stand, generally of brass, stamped out from thin sheets, with Chinese characters and decorations; and were it not for a small imprint of the manufacturer's name on the base, they would be considered of Chinese make. They are inexpensive, of the kind desired by the China-

man, although perhaps not for sale in Hamburg or Berlin. On the other hand, the American article, much more handsome, from our point of view, but also more expensive, is of the same style as is sold on Broadway, in New York.

There is no need to multiply examples. There awaits the American manufacturer an outlet, especially for tools, machinery and other articles in iron and steel. He will find a demand for the smaller and lighter machines, rather than for the larger ones. That is to say, he must appeal first to the individual worker who exists now, rather than aim at the needs of a conglomeration in a factory, which will come about in the future. The tools should be simple in character, easily worked and kept in order, and without the application of quick-return and other mechanical devices so necessary for labor-saving with us. Light wood-working machinery can be made to supplant the present manual-labor methods; and a large field is open for all kinds of pumps, windmills, piping and other articles of hydraulic machinery.

Cotton goods of the finer grades, as well as the coarser which are supplied, household articles of all kinds, glassware, window-glass, wall-paper, and plumbing fixtures will find a ready market, as will also farm equipments, such as light-wheeled vehicles and small agricultural implements of all kinds. In these, as in many manufactured articles, American trade has as yet made little or no impression; and yet the American article has an acknowledged superiority over any other foreign make.

It is necessary for us also to study the Chinaman himself. The English and American traders make but little attempt to learn the language, and, therefore, frequently fail to come into personal contact with the native merchant. They are inclined to leave such negotiations to be conducted through a compradore, a native in the employ of the firm, who makes all the contracts, and who guarantees to his firm all native accounts, receiving a commission for his services. The German, and especially the Japanese, merchants, on the other hand, make a great effort to come into direct relations with those with whom they trade. They are still making use of the compradore system, but within reasonable limits. As to which course is preferable in the long run there can be no question. Our houses should adopt the suggestion made in the report of the Blackburn (England) Chamber of Commerce, "to train in the Chinese spoken language and mercantile customs youths selected . . . for their business capacity. Such a system," the report adds, "would give us a hold over foreign trade in China that present methods can never do."

Finally to be considered, there is the official representative of the United States, the consul. It is bad enough, as our practice is, to send consuls to France, or Germany, or Italy, who are unacquainted with the language of the country. But how much worse to send as our Govern-

ment agents to China, the nation most difficult of all to come into relations with, men without any idea, not only of the language, but of the customs and the idiosyncrasies of the people.

This is not a reflection upon our present staff, many of whom are excellent and worthy men and who are now acquainted with the characteristics of those to whom they are accredited. But under our system, by the time a man understands his duties, he is removed. Nowhere else in the world is there so great a need for a permanent consular service as in China.

The British Government long ago established a separate consular service for the East, entirely distinct from that elsewhere, so that a man once in the Chinese service stays there, and is not likely to be transferred to a European or American post. Secretary Hay has lately made a beginning toward this end by proposing to establish a school at Peking. If the idea is not carried out now, circumstances will compel its adoption later. We should awake to the realization of our opportunities, and unite for the invasion, not only of China, but of other Oriental lands as well.

DISCUSSION AND CORRESPONDENCE.

ENERGY AND WORK OF THE HUMAN BODY.

In discussing 'The Human Body as an Engine,'* I referred to some experiments made at Middletown with the Atwater-Rosa Respiration Calorimeter, in which a man lived several days in each of the experiments in a sealed chamber of about 180 cubic feet capacity, eating, sleeping and working, while under minute observation. The potential energy supplied to the subject of the experiment through the food which he ate was determined by serving him with accurately weighed portions of the various articles of the prescribed diet, and analyzing and burning in a small calorimeter carefully selected samples of the same. The energy yielded by the subject consisted of three portions, all of which were carefully determined. These were: (1) the heat of radiation and respiration which was measured by the calorimeter, (2) mechanical work done within the calorimeter and (3) potential energy carried off in the refuse products of the body. The immediate purpose of the work was to verify experimentally the law of the conservation of energy for the living body; to show that the total energy taken into the body is equal to the sum of all the energy given out by the body during the same period (provided there is no net gain or loss of energy by the body); to show, indeed, that the fundamental law of physics applies to the animal body, as it does to an engine or a dynamo or any other machine or mechanical system. The law has been amply verified for inanimate systems; it seemed desirable to test it for an organic system. The statement was made in the article referred to that "In some cases the man under investigation worked regularly eight hours a day, the work done being measured by apparatus designed for the purpose." Some inquiry having been made as to how this work was measured, and whether it is possible, after all, to do this, the editor has asked me to answer the inquiry through the columns of the MONTHLY.

Confusion often arises in considering questions like the present one through inexact ideas concerning force and work. When force is exerted through a finite distance, work is done and energy is transferred from one body to another; and the work done is equal to the energy so transferred. It is also equal to the force exerted in the direction of the motion multiplied by the distance through which the force acts. For example, when a man lifts a stone he exerts a force equal to that of gravity upon the stone through a certain vertical distance; and the work done is equal to the force exerted (that is, to the weight of the stone) multiplied by the height it is lifted. The energy expended by the body is here transferred to the stone in its elevated position. This energy stored up in the stone is called potential energy, and it remains constant in amount so long as the stone remains at the same level. If the stone falls to a lower level its potential energy is reduced, but kinetic energy equal to the decrease of potential energy appears as heat.

If the man lifts the stone one inch the work is only one thirty-sixth part as much as if he lifts it three feet. If he pull on the stone but does not move it, no work is done, in the mechanical sense. Muscle has contracted and work is doubtless done within the body, but

* POPULAR SCIENCE MONTHLY for September, 1900.

so far as the stone is concerned no work is done. So a man may hold a heavy weight in his hand or on his shoulder, sustaining it with considerable effort against the force of gravity, and yet no work is done on the stone so long as it is not raised to a higher level. If the stone is carried in a horizontal plane, no work is done on the stone; while if it is carried down hill or lowered vertically, *negative* work is done on the stone. That is, since the stone possesses less potential energy at the foot of the hill than at the top (the difference being equal to the weight of the stone multiplied by the difference of altitude), the stone has lost energy, and this energy lost by the stone has been communicated to the man, who has had work done upon him by the stone, albeit he may have lugged it down the hill or lowered it from an elevated position with considerable effort.

When a car is propelled by an electric motor deriving its current from a storage battery carried on board the car, the energy of the car consists of three parts: (A) Mechanical potential energy due to the mass of the car being at some elevation above the surface of the earth. (B) Kinetic energy, due to the motion of the car as a whole and of its parts with respect to one another and the heat of the car. (C) Chemical potential energy stored up in the battery. When the car is running up grade, energy is being expended not only in overcoming friction, but also in lifting the car against the force of gravity. In doing this, energy is transferred from C to A. When the car descends again to its former level the energy stored up in A is given up, less energy is therefore required from the battery to propel the car, and the battery is accordingly in so much spared. If the grade be steep, the motor may actually be driven as a dynamo, and the current which is thereby generated may be stored up in the battery. In this case energy is transferred from A to C, and at the bottom of the hill the energy C may be greater than that at the top. The battery has done negative work on the car coming down the hill; that is, the car has done work on the battery and stored up energy.

The same considerations apply to the animal body. If a man carries himself up a hill, he is doing work upon his body in so elevating it against the force of gravity, and if he weighs 150 pounds and ascends an altitude of 10,000 feet, he has done 1,500,000 foot-pounds of work upon his body. This represents the quantity of energy which has been transferred from his tissues to his body as a mass; from chemical potential energy to mechanical potential energy. The tissues correspond to the storage battery, the muscles to the motor and the man's weight to that of the car. So when the man walks down the mountain again he does negative work, lowering his body (like lowering the car), involving the transfer of potential energy from his body as a mass to his tissues. Just what form the energy takes as it is so transferred is not altogether clear, but the distinction between the potential energy of the body as a mass, due to its elevation above the surface of the earth, and the potential and kinetic energy resident in the tissues of the body, is one of fundamental importance and should be kept clearly in view.

We may consider the man to be a complex machine, weighing, say, 150 pounds and having a quantity of potential and kinetic energy stored up within his body, which store of energy is drawn upon whenever external work is to be done, and which, besides, is being constantly expended in keeping the body warm and performing the internal work of the body. The energy of the body, like that of the electric car, then, consists of three portions, viz.: (A) Mechanical potential energy of the body as a whole, due to its position with respect to the earth. This is zero when it is at the earth's surface, or say the sea level, and increases as it rises above the sea level. (B) Kinetic energy, due to the heat of the body and to the motion of the body as a whole and of its several

parts with respect to each other. (C) A store of chemical potential energy in its tissues and in food undergoing assimilation. Now when a man walks up hill, A increases, B remains nearly constant (increasing slightly), while C decreases rapidly, due partly to the increase of A and partly to the loss of heat by radiation and respiration. When he walks down hill, A is transferred to C or B, or both, and because of this acquisition C decreases more slowly than it would do if it received nothing from A, while yet giving off energy at the same rate. The man does positive work upon his body when he lifts it against the force of gravity, storing up potential energy A; he does negative work when he goes down hill, and the energy A passes to the interior of the body.

Suppose a laborer lifts 20,000 pounds of brick 5 feet; he does 100,000 foot-pounds of work, this energy being transferred from A to the bricks, and it will remain in the bricks as long as they remain at their elevated position. Next, suppose he lowers the same bricks to their former position. This 100,000 foot-pounds of energy is now transferred back from the bricks to the laborer's body. Because he is expending energy all the time he will possess less energy at the end of the task than at the beginning. Nevertheless, he does not lose as much as though he had not received the 100,000 foot-pounds of energy from the bricks, and had given off the same amount of energy in other ways.

We do not understand the process whereby the body converts chemical potential energy of tissue into mechanical energy; that is, we do not understand how the body does work. Still less do we understand how negative work is done; that is, how the body receives energy from without when it lowers a weight or walks down hill. That it does so acquire energy we cannot doubt. But whether it appears at once as heat, or as some other form of energy, and where the energy so received first appears, has not been proved. Neither have experiments been carried out to determine the relation between (1) the quantity of negative work done in a given period, (2) the total heat radiated from the body in the same period, (3) the amounts of oxygen absorbed and carbon dioxid respired, and (4) the excess of energy expended over that expended in the same length of time during rest. Indeed, to repeat the experiments already done with the respiration calorimeter balancing the total income and outgo of energy for a given period, with this important difference, that the subject of the experiment was doing negative work (that is, having work done on him by an external agent) would be an extremely interesting and valuable piece of work.

Consider now what occurs in walking on a level. The foot and leg are lifted, work is done in lifting them, and energy is stored up in them; they are advanced and lowered to the ground, and this stored up mechanical potential energy is then recovered by the system. The center of gravity of the body as a whole is also raised slightly at each step, but the work done in raising it is only equal to the energy yielded by the body when it descends again to the former level. Assuming an absence of friction against the ground and the atmosphere, the total external work done in walking on a level is zero. Force is exerted in holding the body erect or in holding the arm in an extended position. But no work is done in either case, for the force is not exerted through any distance. So also force is exerted by the huge cables which sustain the Brooklyn Bridge against gravity, but no work is done by these cables so long as the bridge is not lifted. Force is exerted by the foundations of a building in resisting the attraction of gravitation upon the mass of the superstructure, but no work is done by the foundation in so sustaining the weight. What the internal work of the body may be when muscle is contracted and force exerted without doing external work is another matter. That question is deserving of careful study, and the respiration calori-

meter might perhaps lend itself to such an inquiry.

In the experiments referred to, the man under investigation received daily a known quantity of potential energy in the form of food. Part of this was converted into external mechanical energy and was measured; of the remainder, part appeared as heat and part was carried away in the refuse products of the body. The internal work of the body is ultimately converted into heat, and appears in the total heat of radiation and respiration. Thus energy is expended in causing the heart to beat and the blood to circulate and the lungs to expand. This internal work is not stored up, but is transformed into heat and radiated away with that which results directly from combustion. But external work done, like turning a grindstone or sawing wood, is not represented in the heat radiations of the body.

In order to do the desired amount of work within the calorimeter, the man operated a stationary bicycle, which was geared to a small dynamo. The front wheel of the bicycle was removed, and the rear wheel served as a driving pulley for the dynamo. The latter generated a current, the energy of which was measured by an ammeter and a volt-meter. When this current passed out of the calorimeter, its energy was not included in the heat measured by the calorimeter. But in some cases the current flowed through an incandescent lamp inside the calorimeter. Then the mechanical energy done by the man was all turned to heat within the calorimeter; part of it through friction in the bicycle and dynamo, part through the electric current which flowed through the lamp. The former was measured as accurately as possible by seeing how much energy was required to drive the bicycle when using the dynamo as a motor, supplying current to the latter from a battery and measuring the energy so supplied by an ammeter and volt-meter. The quantity of heat resulting from this friction must be subtracted from the total heat measured, in order to ascertain the quantity which was given off from the man's body directly as heat. And in those cases where the electric lamp was inside the chamber (and hence the work done by the subject was converted into heat within the chamber) this total amount must be subtracted from the heat measured to give the amount of heat given off as such by the subject of the experiment.

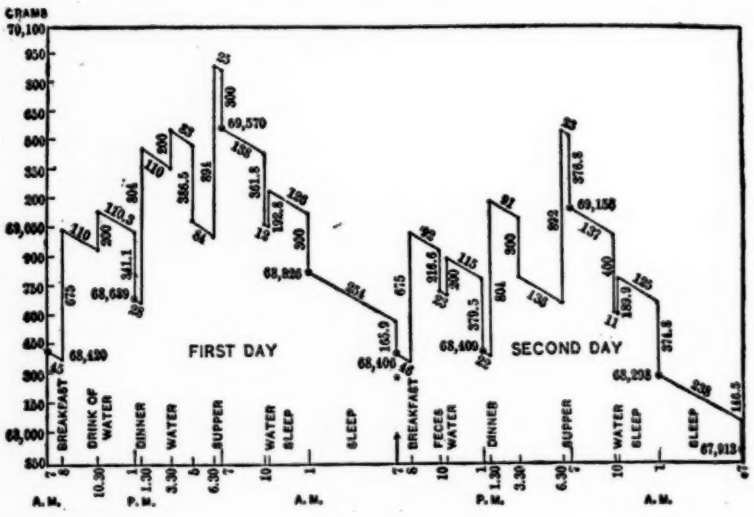
Thus we measure the quantity of external work done; but nothing is here learned about the internal work. The latter is converted into heat within the body and, when radiated away, is measured with the rest by the calorimeter. The amount of external work done in driving this bicycle-dynamo combination in one of the experiments (which continued for 96 hours) was equivalent to 256 large calories per day. This was about 40 watts for eight hours, or 788,000 foot-pounds, or 394 foot-tons. The total quantity of energy yielded was 3,726 large calories on the average for each of the four days. Since 256 is about 7 per cent. of 3,726, we see that the man converted 7 per cent. of the energy contained in his food into mechanical energy, 93 per cent. appearing in the heat of radiation and respiration. This gives the man, regarded as a machine for doing mechanical work, a 24-hour efficiency of 7 per cent. During the eight hours in which work was done the total consumption of energy was about 1,850 calories. Dividing the work done by this figure, we have for the mechanical efficiency during working time, 14 per cent. But there is still another way of reckoning this efficiency. Inasmuch as a large part of the energy supplied to the body would have been required to do internal work and keep the body warm, if no work had been done, we can fairly charge against the work done only the excess of energy supplied during the days when work was done over that required by the same man when no appreciable external work was done. The average quantity of energy

supplied in several experiments in which the man did no considerable external work was 2,500 large calories. The excess in the work experiment was therefore 1,226 calories. Dividing the work done, 256 calories, by the excess of energy absorbed, 1,226, and the quotient is .21. Thus 21 per cent. of this excess of energy absorbed was converted into work, or the efficiency of the man as a machine for doing work is 21 per cent. This is far greater than the efficiency of small portable steam engines, such as could be compared with respect to size or power with a human machine, and equals or surpasses that of the largest compound condensing engines taken in connection with the most perfect water-tube boilers.

The bicycle-dynamo combination is not the most effective device upon which to develop mechanical power; and in the experiments quoted no attempt was made to secure the maximum efficiency of conversion of the potential energy of foodstuffs into mechanical energy. Although many experiments have already been carried out, further experiments are needed to show more fully what the human machine is capable of doing, and what circumstances are favorable to a high efficiency of conversion.

It may be of interest to show how a man's weight varies during twenty-four hours. The accompanying diagrams* give the variation in the weight of the man under investigation in one of the rest experiments; that is, in a four-days' experiment, where no mechanical work was done, except that involved in eating, dressing and making some records and observations within the calorimeter. The routine followed each day was nearly but not exactly the same, and the fluctuations of weight are accordingly similar but not identical each day.

Increase of weight is due to food and drink taken into the body and oxygen respired from the atmosphere. Decrease of weight is due to feces and urine leaving the body, and carbon dioxid and water vapor carried away from the lungs and skin. Part of these changes in weight occur more or less suddenly, while the change due to respiration, in which oxygen is absorbed and carbon dioxid and water vapor are evolved, is gradual. In the diagrams the sudden changes are indicated by vertical lines, the numbers indicating the quantity of the change in grams. The gradual

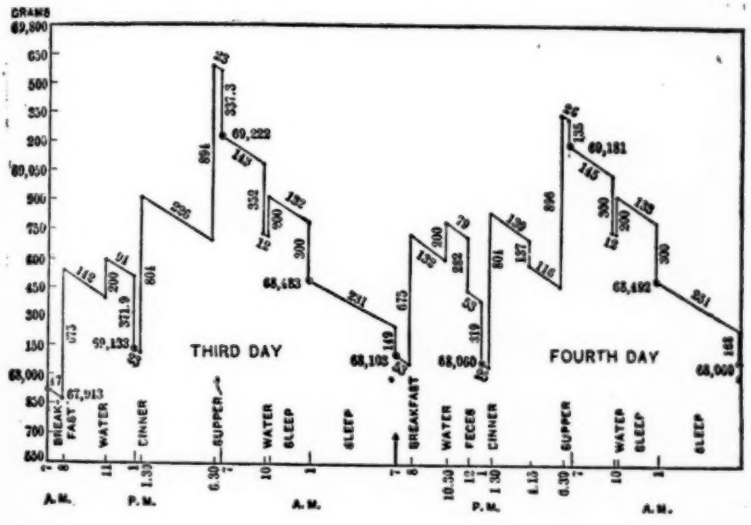


*Copied from an article by the writer in the 'Physical Review' for March, 1900, 'On the Metabolism of Matter in the Living Body.'

changes due to respirations are indicated by sloping lines, the number in each case indicating the net loss in grams; that is, the difference between the quantity of carbon dioxid and water vapor exhaled and the oxygen absorbed. All the vertical lines indicating sudden decrease in weight are due to urine except the two (on the second and fourth days) which are marked 'feces.'

Starting at 7 o'clock on the morning of the first day with a weight of 68,420 grams, the subject loses 45 grams in one hour by respiration. This loss by respiration was determined to be 270 grams in six hours, and in making up this diagram it was assumed to be uniform during the six hours. The loss by carbon dioxid is almost exactly 25 per cent. greater than the gain by oxygen absorbed. Sitting on a good balance, one can literally see one's self grow lighter as one quietly breathes one's self away. Breakfast adds 675 grams, respiration reduces his weight by 110 grams up to 10.30, when a drink of water adds 200 grams; a further loss of 110.3 grams by respiration is followed by a loss of 341 grams of urine, then 28 by respiration, and at 1.30 dinner adds 804 grams. The weight drops during the afternoon and then supper brings it up to the maximum of the day. During the night the weight falls again, so that at 7 o'clock on the second morning it is almost exactly the same as at the start. It is noteworthy that the loss by respiration is nearly as great during sleep as during the morning and afternoon hours, there being a loss of 254 grams in six hours during sleep as compared with 270 in six hours during the day.

The variations in weight in the three succeeding days can be followed from the diagram. These diagrams were made from the records of the experiment, and



the computed weights agreed quite well with actual weighings made at several different times during the experiment.

Such diagrams have not as yet been prepared for work experiments, but they could not fail to be of great interest in the cases we have been considering; namely, where the subject of the experiment does first positive work, then negative work, and, finally, positive and negative work together.

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SCIENTIFIC LITERATURE.

PHOTOGRAPHY OF SOLAR ECLIPSES.

IT is often supposed by readers of popular articles on astronomical photography that the introduction of the methods of 'the new astronomy' has done away, once for all, with the difficulties of the old. The photographic plate has taken the place of the observer's eye and the personal equation is supposed to have been abolished. Those who work in astronomical photography are the first to extol the merits of the new methods. But they are fully aware of difficulties peculiar to them which must be treated very much as if they were errors peculiar to an observer. The plate has its own personal equation. It is impossible to overestimate the benefit to eclipse observations, for example, that has resulted from the introduction of photography as a means of registering the forms and details of the solar corona. Yet the photographic plate has serious failings of its own. Some of them have lately been done away with by a device invented by Mr. Charles Burckhalter, Director of the Chabot Observatory, in Oakland, California; and it is the purpose of this paragraph to exhibit the advance made by Mr. Burckhalter's methods.

The solar corona is very bright near the edge of the sun's disc and fades away gradually till at a distance of some 80 to 100 minutes its brilliancy is about the same as that of the sky-background. If a photograph is taken with a very short exposure, only the brighter parts of the corona are registered on the plate. The fainter portions do not appear at all. If a photograph is taken with an exposure sufficiently long to record the fainter portions, all the inner regions of the corona are much overexposed, and all detail is lost near the sun's edge. By the ordinary methods, then, the corona, as a whole, cannot be exhibited on any single plate. Each exposure is suitable for registering one region, and only one. The corona must be studied on a series of negatives of varying exposures.

Mr. Burckhalter has devised and tried at two eclipses (the India eclipse of 1898 and the Georgia eclipse of 1900) a simple plan which has worked very well. He uses an ordinary photographic telescope and plate, but in front of the plate he places a rapidly revolving shield or diaphragm, cut to such a shape that different portions of the corona have different exposures. At the Georgia eclipse, for example, one of his negatives was exposed for eight seconds, but it was, at the same time, screened from the light so that the equivalent exposure at the sun's edge was only 4-100 of a second; at 4′ from the sun's edge, 0s.32; at 8′, 0s.80; at 12′, 1s.38; at 16′, 1s.76; at 24′, 2s.40; at 34′, 3s.20; at 44′, 4s.00; at 64′, 5s.60; at 94′ and at all greater distances, 8s.00. The resulting negative is extremely fine, and it exhibits the corona as it has never before been seen on a single plate. The bright inner corona and prominences are shown in their true form and brilliancy alongside of the faint polar rays and the delicate masses of the outer coronal extensions. Those who are especially interested should consult Mr. Burckhalter's report (illustrated) in the *Publications of the Astronomical Society of the Pacific*, No. 75, for October, 1900. The advance over previous work of the same kind is so marked that it is to be hoped that this method will be adopted at the Sumatra eclipse of May, 1901.

PSYCHOLOGY AS LITERATURE AND FICTION.

MESSRS. HARPER & BROS. are responsible for the publication of 'Hyp-

notism in Mental and Moral Culture,' by John Duncan Quackenbos, an unfortunate volume which may be permitted to speak for and condemn itself. To begin with, the work was written 'in premeditated ignorance of recent works on hypnotism.' Hypnotism is presented as a miraculous panacea. "A recent experiment of the writer's establishes the fact that disequilibration may be adjusted; a congenital cerebral deficiency overcome; a personality crippled by thought inhibition, mental apathy and defective attention transformed into a personality without a blot upon the brain, and so impending insanity shunted—by the use of hypnotic suggestion as an educational agency." "Differences induced by objective education are obliterated; and the fundamental endowments of that finer spiritual organ in which under God we have our highest being—endowments conferred by Deity on all human souls without favor and without stint—dominate the intellectual life. The divine image is supreme in the man, and creative communication on the broadest lines and on the most exalted planes becomes possible. Hypnotic suggestion is but inspiration. Not only does the subject share the latent knowledge, but he borrows as well the mental tone of the operator. His memory becomes preternaturally impressible. The principles of science, of language, of music, of art, are quickly appropriated and permanently retained for post-hypnotic expression through appropriate channels. Confidence in talent is acquired; and embarrassment, confusion, all admission of inferiority, are banished from the objective life—by placing the superior self in control." Among the patients are "several ladies who are making a profession of fiction writing. To these latter were imparted in hypnosis, first, a knowledge of the canons of narration, viz., the law of selection, which limits the story-teller to appropriate characteristic or individual circumstances; the law of succession," and other laws of like flavor. The result: "In the light of instantaneous apprehension, barrenness gives place to richness of association, the earnest thought and honest toil of the old method to a surprising facility, disinclination to select details to zest in appropriating whatever is available. Opportunity and mood are thus made to coincide, and the subject spontaneously conforms to the eternal principles of style. Under the influence of such inspiration, rapid progress has been made in the chosen field of authorship." The art of acting is equally easily accomplished. "The response of the woman's soul to such suggestions with post-hypnotic import is followed by her speedy ascent to the heights of histrionic art, and by subsequent triumphs on the stage through an apprehension of her own deathless power as revealed by the creative communication of her hypnotist. An actress once so inspired is inspired forever." For music the same formula holds. "The automatic mind is gently wooed to the summits of soul life, where it becomes susceptible to inspiration and burns to launch itself, through music as a medium of artistic expression, into the objective world." Moral perfection is likewise achieved. Here is a typical case before treatment: "Philetas M., aged twenty-one, an adept in all kinds of deviltry; a cigarette fiend; an incorrigible liar, unblushingly denying scarce-cold crimes with the proofs of their commission in our very hands, and constantly deceiving his parents with rotten-hearted promises; a borrower of money under false pretences, and an out-and-out thief for whom jail had no terrors; a gambler; a profligate ready to pawn the clothes on his back at the bidding of town-dowdies; a trencher-knight of the subloins of the Tenderloin," etc.; and this is the appearance after taking: "The weaknesses of the past are forgotten, vice loses its attractions, and the inspired soul seeks to make reparation for its shortcomings by an exaggerated loyalty to the spirit of the moral law. The young man who has regarded with contempt a father's advice and a

mother's love becomes, after treatment, the incarnation of filial reverence and affection. The liar looks his interlocutor in the face and speaks the truth without regard to consequences. The thief parts with all inclination to appropriate what is not his. The libertine accepts the white life. Human saprophytes that thrive on social rottenness are not wholly destitute of moral chlorophyl." Nor is this all. By the same means, "Habits of thought concentration may be made to take the place of habits of rambling, ability to use grammatical English for uncertainty in syntax, a taste that approves elegance for an inclination to slang." Though potent for good, this panacea refuses to work ill. "Fortunately for the protection of society, the power of suggestion to deprave is providentially limited, while its influence for good is without horizon. A mesmerizee quickly discovers the hypocrite in a suggestionist, and a pure soul will always revolt at the intrusion of a sordid or sensual self and spontaneously repel its advances." That the suggestionist must have unusual gifts to accomplish such vast results seems natural enough. "A practitioner of hypnotism should be a proficient in the physical sciences, in literature, language, belles-lettres, art, sociology and theology." "Ignorance in an operator is a disqualifying defect; soul-exalting suggestions are full of atmosphere." Nor is it surprising to learn that the mesmerizee evidences "supranormal perceptive powers, possessed by subliminal selfs, acting at a distance from their physical bodies (a rational explanation of clairvoyance and clairaudience), or of automatic communications between the subliminal selfs of such unconscious mediums and outside personalities not human, who are cognizant of the events described, and are independent of time and space limitations;" and that "human beings are hypnotizable by other human beings, between whom and themselves exists a peculiar sympathy or harmonious relationship known as *rapport*."

There is no need to continue. If the above citations prevent the spread of false notions regarding the contents and character of the work they will in part have fulfilled their purpose. That the volume contains interesting, possibly valuable observations, may be true; but the general distrust of any results so sensationally presented will deservedly prevent recognition of any sound contribution of fact that may happen to be buried beneath this tinsel and paste. Were it not for the 'premeditated ignorance,' the author might have known of similar observations more soberly presented by other writers; and he might have been induced by a knowledge of the present status of hypnotism to present his own results with more reserve, proportion and scientific acceptability. It is difficult to say whether the author offends most deeply our scientific sensibilities by his extravagant, false and misleading representations, or our æsthetic sense by his grotesque and tactless manner of presentation, or our moral judgment by his disregard of obvious relations and his irrelevant and officious appeal to religious beliefs. On account of its popular tone, such a volume has great power for evil, and the condemnation of author and publisher for such abuse of a popular interest should be expressed in no uncertain terms.

'MEDICINE AND THE MIND,' translated from the French of Dr. Maurice de Fleury by Stacy B. Collins, M. D., and published by Downey & Co., is the type of work which the scientifically-minded are likely to dismiss as too 'literary,' and the littérateur to disregard as too scientific. Neither disparagement is quite warranted, however natural. If one assumes a proper attitude towards the volume—or perhaps one should say, finds himself in a sympathetic mood for this kind of reading—he may find attraction, suggestiveness and profit in its perusal. But it is distinctly a kind of writing to which the Anglo-Saxon mind is unresponsive; our standards of popular science are totally different in ideal and execution from

those of our Gaelic colleagues; and, accordingly, when a book such as Dr. Fleury's leaves its native soil, it comes in contact with forms of critical judgment which it cannot successfully meet. As the author himself almost naively notes, in contrasting French works with those of an English writer, Sir John Lubbock, "With us a philosopher writes books for his own renown. Sir John Lubbock thinks of himself not at all." Dr. Fleury follows the French ideal and produces a chatty volume thoroughly infused with his personal opinions and interests, kaleidoscopic in scope, rather aimless in design, literary in form, and, judged by our own ideals, a very bad exemplar for popular science.

The general point of view is that of a physician who wishes to record for the benefit of other types of professional men, the medical aspect of the large and ever-present problems of civilization. From responsibility in cases of crime, and the methods in use at the Salpêtrière, to an essay on the bad effects of tobacco, and the proper regimen for literary men (illustrated by copious testimonials from men of literary note); and again from disquisitions on the effects of serum and other liquids hypodermically applied and an account of the nervous system, through discussions of mental and physical fatigue and the treatment of indolence and melancholy, to the psychology of love and anger as morbid passions, and the 'physiological analysis of flirtation,'—the volume proceeds at times interestingly, often touching upon new and significant observation, but always aimlessly, self-consciously and with a strained attempt to introduce novelty and paradox. When the author remarks "who knows but the twentieth century may rewrite Werther in its own way, with figures in the text, as a medical publication," he suggests only a moderate exaggeration of some of his own pages. The scientific point of view and useful scientific writing are not dependent upon diagrams and phrases, but on the natural outcome of fullness of learning, of a fundamental training and a combination of enthusiasm and skill. Dr. Fleury's book affords glimpses of an attractive personality endowed with some of these requisites; but his volume can have little influence upon the English reading public.

Of translations, as of the dead, it is generally best to say *nihil nisi bonum*. But the imperfections of the present task are all of that totally unnecessary type which makes them particularly aggravating. The foreignness of the presentation is left unmitigated by skillful phrasing; the existence of appropriate technical terms in English is ignored, and minor errors (such as the wrong retranslation of an English work cited by the French author) are numerous.

PROF. FLOURNOY'S skillful description of a remarkable case of sub-conscious automatism was noticed in a recent issue of this Monthly. It is in every way worthy of presentation to English readers; and such readers are under obligations to Messrs. Harper & Bros. and the translator for the creditable appearance of the English volume. The translation is fluent and acceptable, and the composition of the book eminently satisfactory. Apart from the general query as to the desirability of placing a volume of this type before the public at large in a form intended to suggest its popular assimilability, the temper of the translator's preface demands a word of comment and of protest. To present this volume as a contribution to the mystical aspect of that composite activity, the results of which are denominated 'Psychical Research,' is a wrong to the author's purposes and (with few exceptions) is antagonistic to his own point of view. To put forward the volume as a contribution to a line of investigation that shall scientifically prove to be 'the preamble of all religions,' that shall demonstrate unsuspected and anomalous mental powers, and all but demonstrate immortality, to claim that for any one skeptically inclined and out

of harmony with this point of view 'the book will have no interest'—all this serves to place the entire volume in so misleading and unfortunate a position that it would have been far better, rather than have it thus introduced, to have left the work untranslated. Under its present auspices it will prove to be a useful convenience to many, but a source of misconception and a stumbling-block to many more.

EDUCATION.

DURING the later part of the eighteenth century the conception of education as one phase of the development of the individual was established. There followed attention to the methodological aspect of the subject which resulted in the basing of the method of education upon psychology, instead of upon more or less fantastic analogies with nature. During the latter half of the present century has been established the conception of education as a social process, as one phase of human development. As a result, the historical and social aspects of education are becoming more scientific. There has been no history or historical sketch of education for the English reading public that possessed historic and scientific value until the recent appearance of Prof. Thomas Davidson's 'History of Education.' The author defines education as conscious human evolution and attempts to sketch the history of education in terms of dominant evolutionary thought. Frequently the author is guilty of that generality that has brought much of sociological thought into disrepute. His definition of education is so broad that it would include political and other phases of evolution that are conscious processes so far as the race is concerned. However, the revision of old ideas or the formulation of new ones is certain to provoke disagreement concerning essentials or details. It is the attempt that is significant in this case. It is but an earnest of the future. There is further evidence to this more scientific conception of the history of education. Hitherto the historical aspect of education has not passed beyond the biographical stage. But educational biography is now being written from this broader point of view. The interest is less in the individual and more in his relation to social practices and developing ideas. This attitude is best illustrated in the issues of the 'Great Educator Series,' edited by Prof. Nicholas Murray Butler. The latest issue, 'Comenius and the Beginnings of Educational Reform,' by Will S. Monroe, is well up to the higher standard set by previous issues. Comenius was to education what his contemporaries, Bacon and Descartes, were to science and philosophy. A biographical sketch of Comenius from this point of view, such as Mr. Monroe gives, is a valuable contribution to the literature of the new aspect of education.

DR. L. VIERECK publishes in the *Educational Review* an article narrating how even in the German gymnasium Latin is losing its traditional position. A movement is gaining ground looking toward beginning the study of Latin not in the lowest class of the gymnasium, but only after three years, thus leaving six years for the language. In this case Greek is begun two years later and is confined to the last four years of the course. This plan has the obvious advantage of not requiring boys to decide on their career in life at the age of ten years, but permits students of the 'real' gymnasium and of the traditional gymnasium to carry on the same studies for the first three years. The system, which was first tried in Frankfort in 1892, had a year ago been adopted in twenty-one schools and appears to be favored by the Prussian Government. Other straws showing how the current is setting in Germany are the establishment within a year of a doctorate in applied science and the decision that hereafter the doctor's diploma shall be written in German instead of Latin.

THE PROGRESS OF SCIENCE.

THE statue of Lavoisier, shown in the frontispiece of this number, was unveiled at Paris on the 27th of July. It stands facing the Rue Tronchet, near the house in which Lavoisier dwelt. The figure, of bronze, stands upon a granite pedestal, ornamented by bas-reliefs representing Lavoisier before his colleagues at the Academy, and at work in his laboratory. M. Leygues presided at the ceremony, at which the members of the international congress of chemistry were present. In the course of the address written for the occasion M. Berthelot characterized Lavoisier's work as follows: "The labors of Lavoisier are related to a fundamental discovery from which they all spring, namely, the discovery of the chemical constitution of matter and of the difference between bodies possessing weight and imponderable forces—heat, light, electricity—the influence of which extends over these bodies. The discovery of this difference overturned the old ideas handed down from antiquity and held till the end of the last century." Lavoisier was a notable example of the excellence of scientific men in other than scientific fields of activity. He wrote a good book on education, was an efficient officer in a number of public undertakings, and was for some years 'fermier général.' His scientific work is summed up by the inscription on the pedestal of the monument: 'Fondateur de la chimie moderne.'

THERE is now evidence that yellow fever, as well as malaria, is caused by inoculation by mosquitoes which serve as the intermediate hosts of the parasites. Drs. Reed, Carroll, Agrámonte and Lazear, who were appointed last summer by the Surgeon-General to investigate infectious diseases in Cuba, have in a preliminary report of their work denied that the bacillus icteroides of Sanarelli is the cause of yellow fever. In general they have not found it present in the blood of yellow fever patients or in the organs of those who have died of the disease, and consider that when present it is a secondary invader. After these results had been reached they tested the hypothesis advanced by Dr. Carlos J. Finlay of Havana in 1881 that yellow fever is transmitted from person to person by mosquitoes. Mosquitoes which had bitten fever patients were allowed to bite eleven persons. In nine cases no evil results followed, but in two cases, Dr. Carroll himself being one, regular attacks of yellow fever followed. It is true that in these cases there was a possibility of infection from other sources, but since out of 1,400 non-immune Americans at the Columbia Barracks there were in two months only three cases and since of the three two had been bitten within five days of the commencement of their attacks by contaminated mosquitoes, the board seems justified in assigning the rôle of efficient cause to the mosquitoes. The positive evidence is increased by the sad history of Dr. Lazear, one of the investigating board. Dr. Lazear was one of the nine who had not suffered in the inoculation experiment just described. While working with yellow fever patients he was bitten by a mosquito, which because of the previous experiment he did not even attempt to avoid. He was bitten on September 13, and became ill on September 17 with the fever, which thereafter ran its course, ending in death. It was not demonstrated that this particular mosquito had previously bitten any yellow fever patient, but of course there was every opportunity for it to do so. Dr. Reed

and his associates feel justified in the following conclusion: "The mosquito serves as the intermediate host for the parasite of yellow fever, and it is highly probable that the disease is only propagated through the bite of this insect."

ONE of the most obscure points in chemistry is the action of ferments. These have been grouped in two classes: Organized ferments like the yeast plant, or the *mycoderma aceti*, which oxidize alcohol to acetic acid; and the unorganized ferments, like diastase, which convert starch into sugar. In both cases a very small quantity of the ferment is capable of converting an indefinitely large amount of the fermenting substance into the fermented product, although the ferment itself does not enter as such into the reaction. Further, the action of ferments can be inhibited by heat and by the action of certain substances which act as poisons. Recent investigations seem to show that the organized ferments may owe their action to unorganized ferments which they secrete. More recently attention has been called by Bredig and von Berneck to the similarity between the action of ferments, and what has been called contact action of metals. For example, finely divided platinum can oxidize alcohol to acetic acid, and can invert cane sugar. Much more marked is the action of a solution of colloidal platinum, obtained by passing a strong current of electricity between platinum poles under water. The action of the platinum in this condition is remarkably like that of a ferment. When its effect upon hydrogen peroxide was studied it was found that one part in about 350,000,000 parts of water was sufficient to decompose hydrogen peroxide appreciably. Minute traces of certain poisons affect the reaction strongly; especially is this true of prussic acid, hydrogen sulfid and corrosive sublimate. Like many ferments the platinum solution gradually recovers from the poisonous effects of traces of potassium cyanid. It also appears that the platinum plays no chemical part in the reaction, and thus it is apparently a true ferment. It seems probable that the study of these inorganic ferments may throw much light upon the action of the very complicated organic ferments.

WHEN the discovery was made some ten years ago that leguminous plants are able to assimilate the free nitrogen of the atmosphere, and thus to supply themselves with one of the necessary elements of plant food, its importance to agriculture as an economical means of maintaining soil fertility was recognized almost immediately. In working out the practical application of the discovery it was found that the micro-organisms which effect this nitrogen assimilation are not the same for all kinds of legumes, but that different kinds have their specific organisms, and furthermore that these micro-organisms are not universally disseminated through the soil. This led to inoculation of the soil, either with pure cultures of the specific bacteria or with soil from a field known to contain them in abundance. What seemed so simple theoretically has been found in practice to be only partially successful, so that the progress in its application has been somewhat delayed. A very interesting account of experiments in inoculating soils for the growth of the soy bean has recently been published by the Kansas Experiment Station as Bulletin No. 96. It is one of the most successful attempts at soil inoculation on a large scale that has been reported in this country or in Europe, where this method for promoting nitrogen assimilation was first suggested. It was found that the Kansas soil contained none of the organisms necessary for the soy bean, and that in such soil the roots produced none of the tubercles which are intimately associated with nitrogen assimilation. A quantity of soil was obtained from the Massachusetts Experiment Station, where the soy bean had been grown for several years, and mixed in very small proportion with the Kansas soil, with the result that

the soy bean plants produced root tubercles abundantly, indicating that they were drawing their nitrogen from the air. Local soil which had once been inoculated and produced a crop of soy beans was found to be suitable material for inoculating other soils; and a practical method for treating large fields has been worked out and tested through several seasons. The result is especially important as the soy bean is well suited to a wide range of country, and aside from being a valuable forage crop its growth materially enriches the soil.

THE recent announcements of the census bureau, which have been widely circulated in the daily press, throw light on a sociological question often discussed. It has been said that the course of population is toward the great cities, that the metropolis is swallowing up the county centers and small cities. A recent prophet of the future made the England of his fiction a single great city with the rest of the country as its farm and garden. Some alarm has been caused lest this supposed tendency to centralization of population prove disastrous to nervous health and moral welfare. It now appears that such a tendency does not exist. For the eighty-one small cities, those of from 25,000 to 50,000, have increased during the last decade practically as fast as the nineteen great cities of over 200,000, namely, about 32 per cent. New York, it is true, has increased 37.8 per cent. The rate of increase of the cities above 25,000 is about 11 per cent. higher than that of the country at large, but there is no cause for sociologists to lament this difference. The inhabitants of the hundred and twenty cities under 100,000 have in many ways a superior intellectual and moral environment. They are freed from the petty annoyances of rural life, its isolation from broadening institutions and its emptiness of appeal to ambition, without losing outdoor freedom or the chance of participation in community life. They enjoy the good schools, libraries, entertainments, the municipal improvements, the services of superior professional men, etc., of great cities, without suffering from metropolitan restrictions, abuses and vices. The small city is in a measure the golden mean among dwelling-places. It would be interesting to observe on a large scale the magnitude of another great movement in population, that connected with the growth of suburbs. The natural supposition is that the rate of increase of the suburbs has been very much above the average even of the cities. In so far as the nature of our surroundings determines our make-up, such new conditions as we have in suburban life are of vital interest to the student of human nature.

THE growth of interest in forestry, one of the youngest of the applied sciences, is attested by the establishment this year of the Yale Forest School, which confers the degree of Master of Forestry on graduates who have obtained the bachelor's degree elsewhere. At the opening of the school there were registered seven regular students, besides seventeen from other departments of the University. The residence of the late Professor O. C. Marsh is used as a school building. Lecture-rooms, a library, a laboratory and an herbarium room have been furnished with such equipment as has been found necessary for the present requirements of the school. A considerable amount of museum material has already been acquired and is being classified and arranged as rapidly as possible. The grounds about the building, ten acres in extent, are already covered with a great variety of trees and shrubs, both native and foreign, and it is the intention to plant a considerable number of varieties which are not represented. A forest nursery will be established on the grounds, but the regular forest planting will be done on waste land on the outskirts of New Haven. The New Haven Water Company has offered to the school the use of several hundred acres

of woodland for the practical field work of the students, and several other owners have expressed their desire to devote their wood-lots to this purpose.

SUCH schools as the Yale Forest School and the thoroughly equipped school at Cornell under Professor Fernow's direction meet a definite, practical need, for it is an undeniable fact that the supply of lumber is being diminished beyond safety. Twenty million dollars' worth of native lumber is used annually in the manufacture of wood-pulp alone. Nearly half of the original resources of Washington Territory, the home of supposedly inexhaustible forests, have been used. Indiana once possessed 28,000 square miles covered with valuable timber. It sent timber to the East in large quantities, but now must import 82 per cent. of the lumber it uses. Lumbermen from the Lake States are now taking up timber land on the Pacific coast. Experts agree that if things had been left to take their natural course, a timber famine would have been the probable fate of the next generation or two. The Government with its forest preserves and the awakened landowner with economical methods of timber-cutting will delay and probably avert such a catastrophe, but a future scarcity in lumber is by no means the only bad result of a *laissez faire* policy regarding forests. The forests are the guardians of the water supply; useful water power, regular irrigation and the absence of dangerous freshets are all dependent on the proper condition of the vegetation of watersheds. It is supposed that the freshet which caused the Johnstown flood of May, 1889, was due in part to the denudation of the Mill Creek watershed, and at the request of the Johnstown Water Company this region has been examined by experts from the Division of Forestry of the United States Department of Agriculture, who have recommended that where the land has not been covered by a second growth, it be planted and that careful protection against fire be given to the whole district. When one considers that similar measures, if taken a generation ago, might have prevented the loss of $10,000,000 worth of property, to say nothing of the tremendous loss of life at the Johnstown disaster, one realizes the importance of forest preservation as a prophylactic against floods. We should teach even the children in the schools Humboldt's warning, "In felling trees growing on the sides and summits of mountains, men under all climates prepare for subsequent generations two calamities at once—a lack of firewood and a lack of water."

THESE national forest reservations are located in the western third of the country, and agitation is now in progress for similar reservations in Minnesota at the head-waters of the Mississippi and in the Southern Appalachians in the western part of North Carolina. The proposed Minnesota Park would include over 200,000 acres of water surface and over 600,000 acres of land. It would serve as a game preserve, as well as a profitable forest and an assurance to an important water supply. The only objection seems to be on the ground of the expense of purchase of Indian rights, which General Andrews, Chief Forest Warden of the State, estimates as not over $75,000 per year. $2,250,000 has this year been devoted for deepening and improving the Mississippi River. Yet this is dependent on the proper treatment of the very region in question. The passage of the bill was apparently favored by all those competent to judge of the case. It was postponed and will probably be again considered in December. Concerning the proposed Southern Appalachian reservation Prof. J. A. Holmes said at the New York meeting of the American Forestry Association: "Such a reserve, if judiciously managed, will pay a good interest on the investment, besides proving of inestimable value to the people of this country as a public resort for health and pleasure, as a lesson in practical forestry, and as

a means of preserving the head-waters of important rivers."

Two lines of work by the Federal Government along the line of forest preservation are especially worth comment. One is the attempt to get an exact estimate of just what forests the country possesses and just what conditions they are in. This knowledge is required as a basis for all theoretical deductions, and as a starting point for all practical measures. This work is now being extensively carried out by the United States Geological Survey. The other is the attempt definitely to assist land-owners to develop wisely their forest lands and thus to spread over the country practical acquaintance with the principles of forest management. This work is in the hands of the Division of Forestry of the Department of Agriculture. In the nineteenth and twentieth reports of the Geological Survey, Mr. Gannett gives the following statistics concerning the area of woodland in the United States. Of the whole country 37 per cent. is wooded; along the Atlantic border the percentage varies from 40 to 80 per cent.; in Ohio, it is 23 per cent.; in Illinois, 18 per cent.; in Kansas, 7 per cent.; in North Dakota, 1 per cent.; in California, 22 per cent., and in Washington, 71 per cent. The areas reserved and their percentage of the total area of the State and of the wooded area of the State are as follows:

State.	Area in Reservation. Sq. Miles.	Per Cent. of Total Area.	Per Cent. of Wooded Area.
Arizona	6,285	6	27
California ...	13,509	9	30
Colorado	4,848	5	15
Idaho	6,264	7	18
Montana	7,885	5	19
New Mexico.	4,273	3	18
Oregon	7,271	8	13
South Dakota	1,893	2	76
Utah	1,474	2	15
Washington .	12,672	19	27
Wyoming ...	4,994	5	40

ONE of the most interesting questions concerning human nature is the degree to which special aptitudes may appear as the result of innate organic conditions quite apart from experience. It is well enough known that general mental ability is born in us if we have it at all, but we do not know so well how far any special ability, for instance in mathematics, music or sculpture, is due to inborn structural or functional peculiarities. The 'prodigies' in special fields may be instanced as evidence that such highly specialized gifts are inborn, but in some cases interest in the facts concerned and the habit of thinking about them seem to be sufficient to account for the prodigy's success. The latest mathematical prodigy, a boy who has been carefully studied by Professor Bryan and Dr. Lindley of Indiana University, seemed to owe his success to the habit of constantly thinking about numbers. Any intelligent person who would be as much engaged in the pursuit might do as well. It is hard, however, to explain in this way the case of the musical prodigy exhibited before the International Congress of Psychologists by M. Charles Richet. The boy, then three years, seven months and seven days old, played the piano with at times remarkable skill in both technique and expression, but especially in the latter. He knows a score of pieces by heart, all of which he has learned by ear. If twenty or thirty measures are played before him he can then play them. He also, though with more difficulty, plays on the piano tunes he has heard sung. Of his inventiveness Professor Richet said: "It is certain that when Pepito starts to improvise, he is almost never at a loss, and he often finds extremely interesting melodies which appear more or less new to all those present. There is a variety and richness of tone which would perhaps be astonishing if he were a professional musician, but which in a child three years and a half old are absolutely overwhelming." In all else than music he seems to be an ordinary child. Pepito, according to his mother's narrative, was a good player from the start. His first performance was to play throughout a

piece which she had played a number of times. This he did absolutely independently of any teaching whatever. Only a special anatomical basis for musical ability seems competent to explain a case like this.

AMONG recent events of scientific interest, we note the following: Dr. Henry S. Pritchett, superintendent of the Coast and Geodetic Survey, was inaugurated as president of the Massachusetts Institute of Technology on October 24.—Sir Michael Foster has been reelected a member of the British Parliament, representing the University of London.—Cambridge University has conferred the degree of Doctor of Science on Professor S. P. Langley, director of the Smithsonian Institution.—Professor George F. Barker, for twenty-eight years professor of physics in the University of Pennsylvania, and Professor F. H. Bonney, for thirty-three years professor of geology in University College, London, have retired.—A committee has been appointed to erect a memorial to the late Spencer F. Baird at Wood's Holl. Subscriptions may be sent to the Hon. E. G. Blackford, Fulton Market, New York City.—The Rumford Committee of the American Academy of Arts and Sciences has voted a grant of $200 to Mr. C. E. Mendenhall of Williams College for the furtherance of his investigations on a hollow bolometer, and a grant of $500 to Professor George E. Hale of the Yerkes Observatory in furtherance of his researches in connection with the application of the radiometer and a study of the infra-red spectrum of the chromosphere. — Professor Ernst Haeckel is at present in Java, seeking for further remains of *Pithecanthropus erectus*.—Dr. Robert Koch has returned to Berlin after fifteen months spent in the study of malaria, chiefly in the German colonies.—Harvard Observatory has sent an expedition to Kingston, Jamaica, to observe the planet Eros in its approaching opposition.—Mr. E. P. Baldwin is planning an expedition to the North Polar regions, the expenses of which will be defrayed by Mr. Ziegler, of New York City.—The New York Board of Health is building, at a cost of $20,000, a laboratory to be wholly devoted to the study of the bubonic plague.—The great Serpent Mound of Ohio, which has long been a subject of study and research for American archeologists, has been given by the Harvard Corporation to the Ohio State Archeological and Historical Society.—The fine new lecture hall of the American Museum of Natural History was opened with appropriate exercises on Tuesday, October 30. At the same time the new anthropological collections were exhibited.—The new National Museum at Munich, containing the collection of Bavarian antiquities, has been opened, and the valuable collections can be viewed to much better advantage than hitherto. The building contains more than a hundred rooms and has been erected at a cost of about $1,000,000.—The Authors' Catalogue of the British Museum, containing four hundered large volumes and numerous supplements, has now been completed. The compilation of the catalogue has occupied twenty years and cost $200,000. A subject-catalogue is now in course of preparation.—The Russian Government has decided to adopt the metric system of weights and measures, and the ministry of finance is now engaged in considering the time and manner of introducing this reform.